TURING 图灵新知

全彩印刷

迷茫的旅行商

一个无处不在的计算机算法问题



[美] William J. Cook 著　　隋春宁 译

In Pursuit of the Traveling Salesman
Mathematics at the Limits of Computation

人民邮电出版社
POSTS & TELECOM PRESS

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> ——Geoff Mack[illegible]

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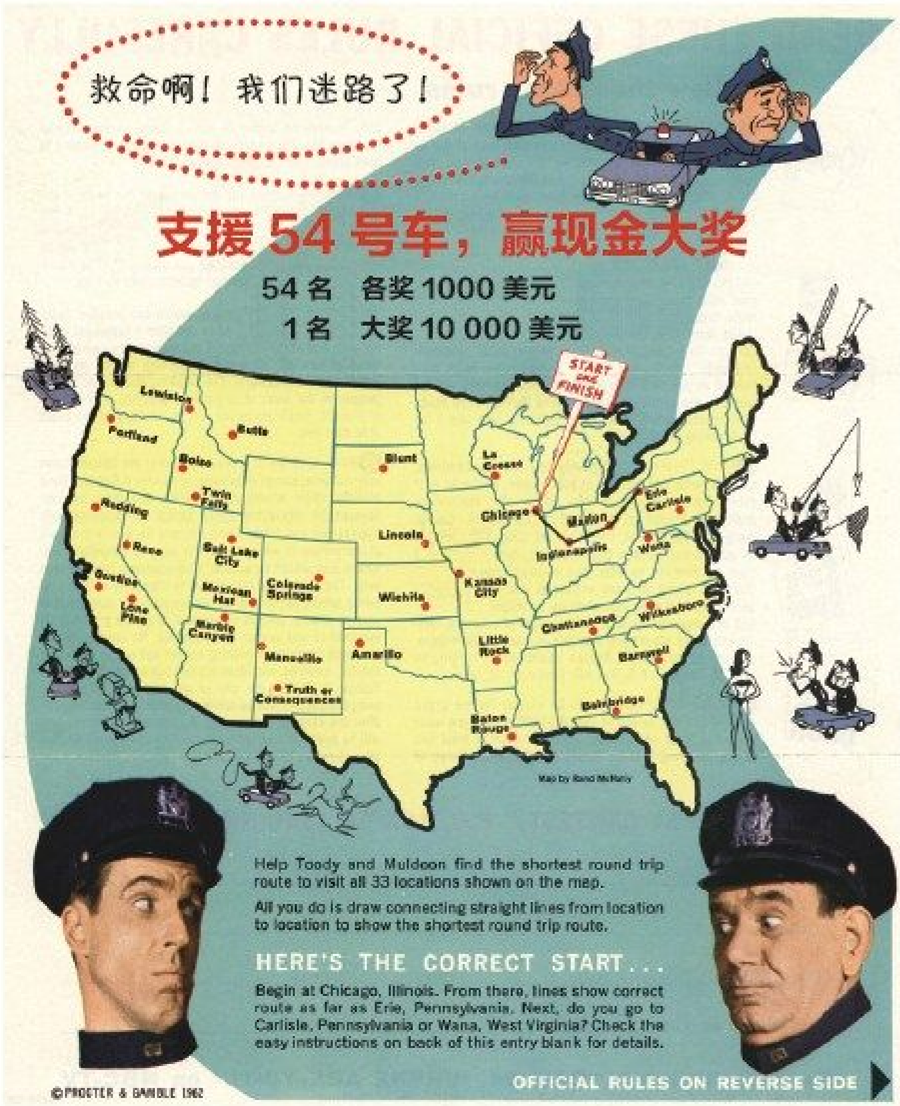
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1. Menger (1931).

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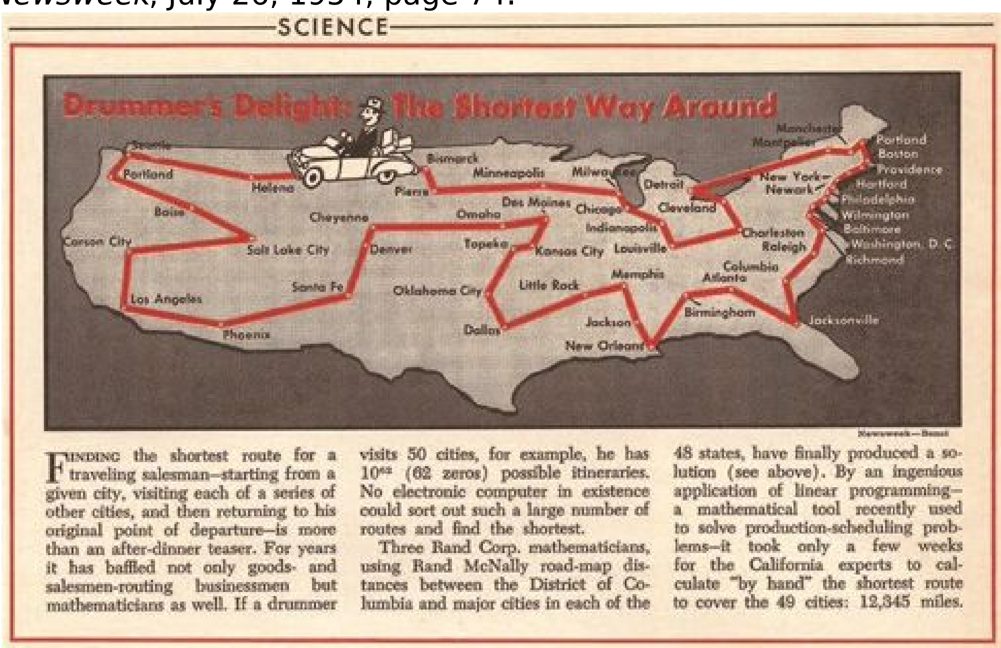
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4. Little, J. D. C., et al. 1963. Operations Research 11, 972–989.

[illegible]1954[illegible]48[illegible]48[illegible]20[illegible]30[illegible][5]

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SCIENCE

Drummer's Delight: The Shortest Way Around

Finding the shortest route for a traveling salesman—starting from a given city, visiting each of a series of other cities, and then returning to his original point of departure—is more than an after-dinner teaser. For years it has baffled not only goods- and salesmen-routing businessmen but mathematicians as well. If a drummer visits 50 cities, for example, he has 10^{62} (62 zeros) possible itineraries. No electronic computer in existence could sort out such a large number of routes and find the shortest.

Three Rand Corp. mathematicians, using Rand McNally road-map distances between the District of Columbia and major cities in each of the 48 states, have finally produced a solution (see above). By an ingenious application of linear programming—a mathematical tool recently used to solve production-scheduling problems—it took only a few weeks for the California experts to calculate "by hand" the shortest route to cover the 49 cities: 12,345 miles.

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6. Karg, R. L., G. L. Thompson. 1964. Management Science 10, 225–248.



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1. [illegible]G. Dozois[illegible]“The Year's Best Science Fiction”[illegible]2000[illegible]2001[illegible]St. Martin's Press[illegible]2010[illegible]7[illegible]54~64[illegible]——[illegible]

> [illegible]

——Merrill Flood[illegible]1956[illegible][2]

2. Flood, M. M. 1956. Operations Research 4, 61–75.

> [illegible]

——Jack Edmonds[illegible]1967[illegible][3]

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> [illegible]

——Richard Karp[illegible]1972[illegible][4]

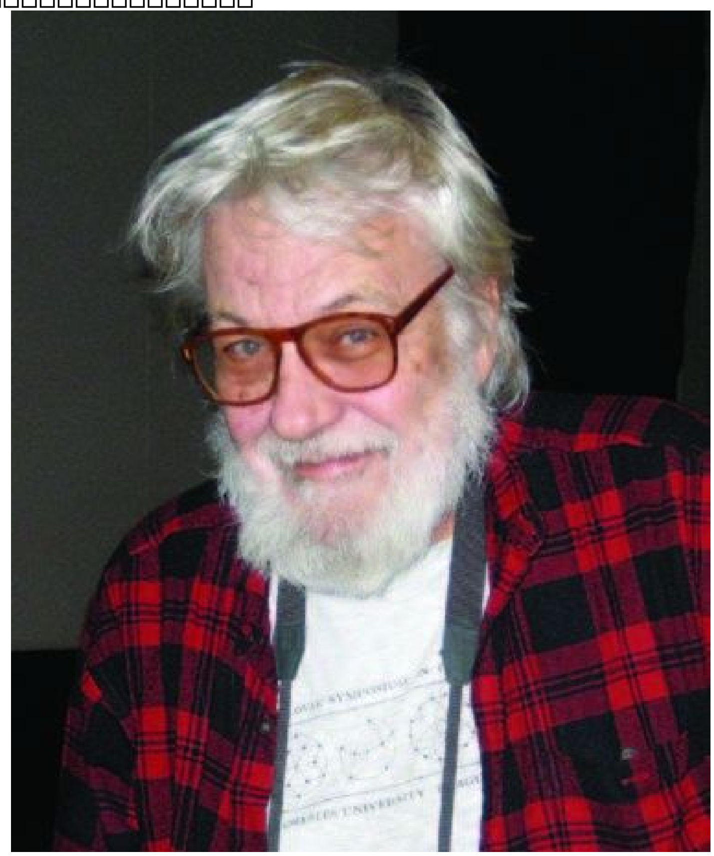
4. Karp (1972).

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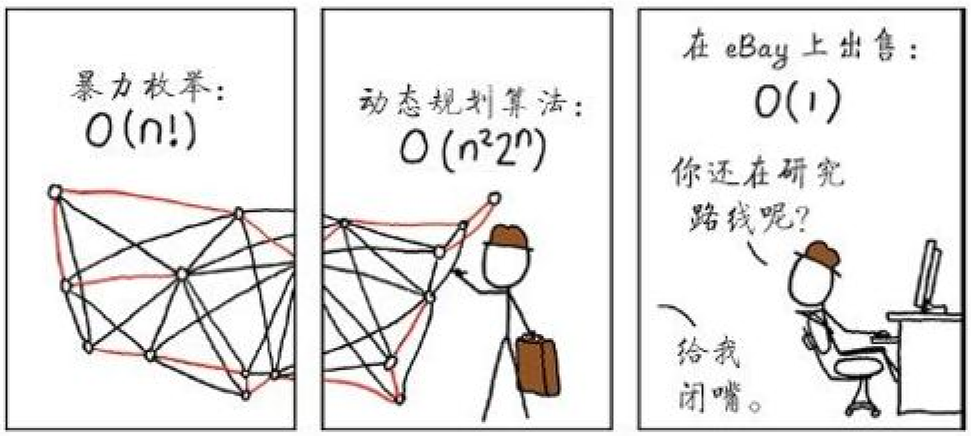
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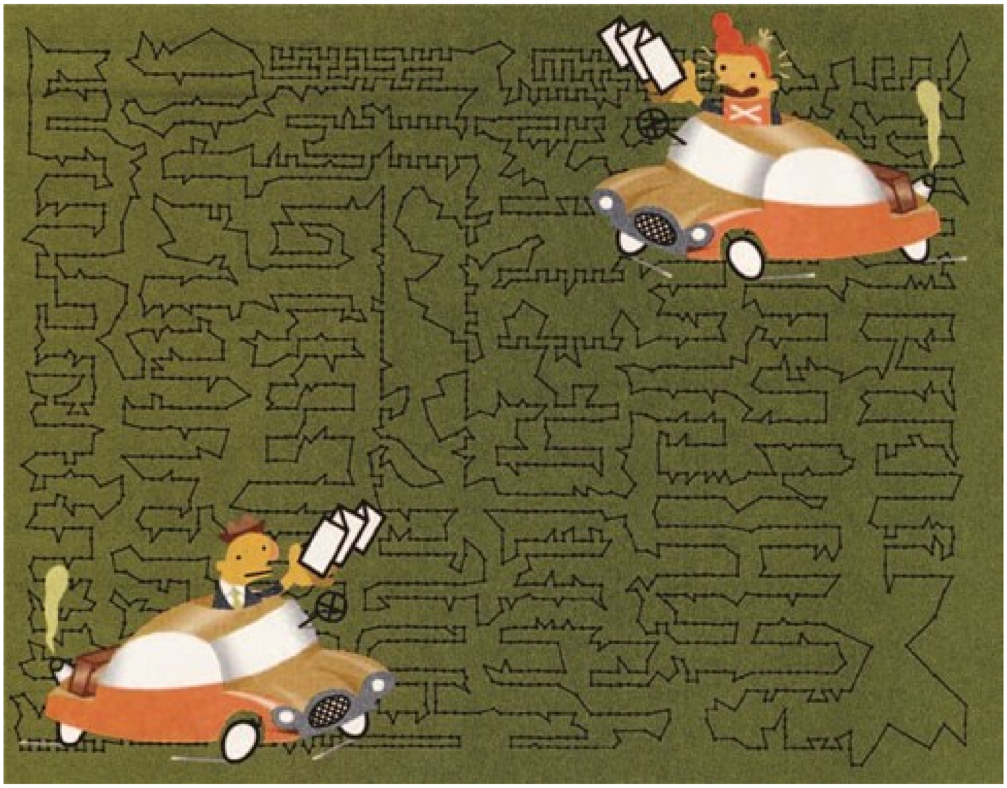
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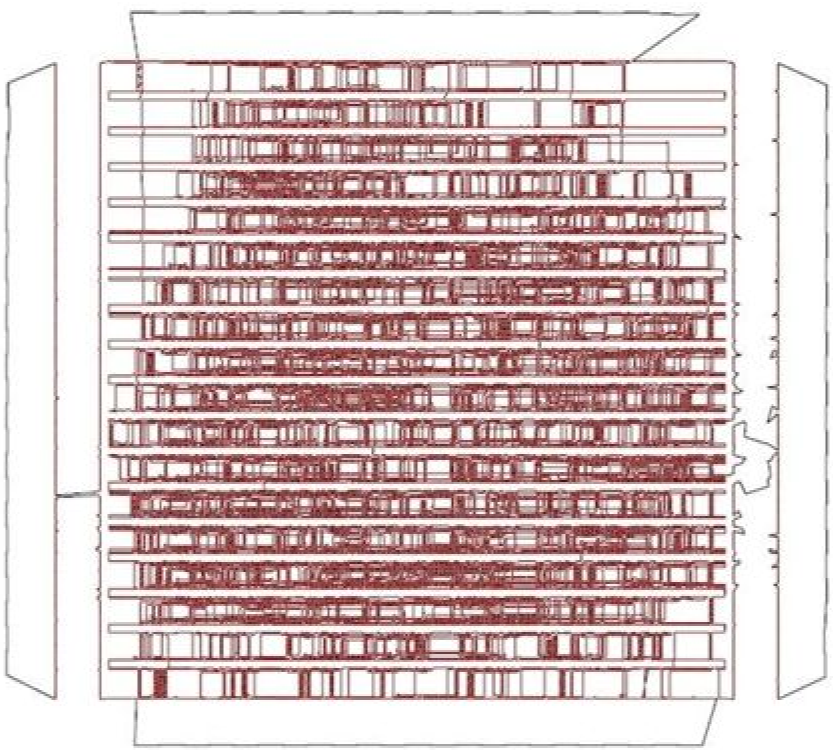
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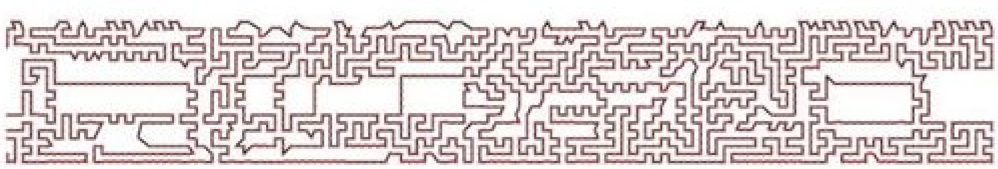
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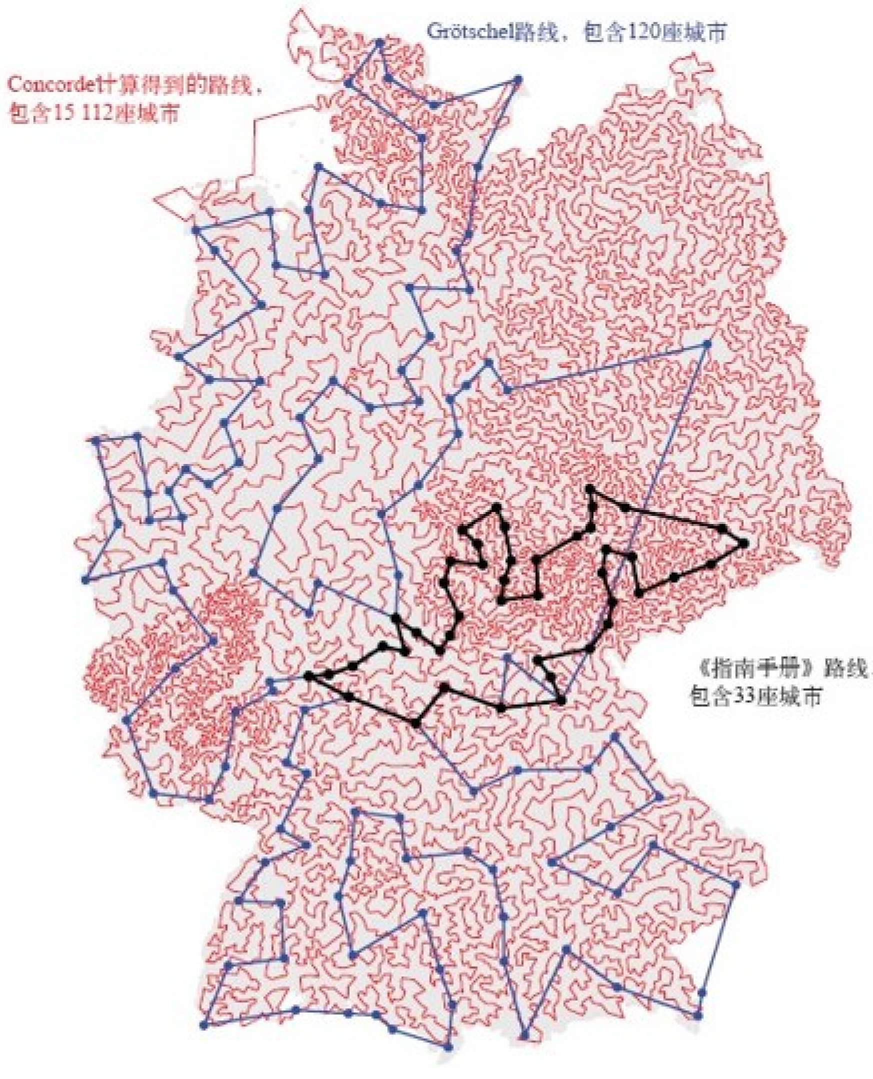
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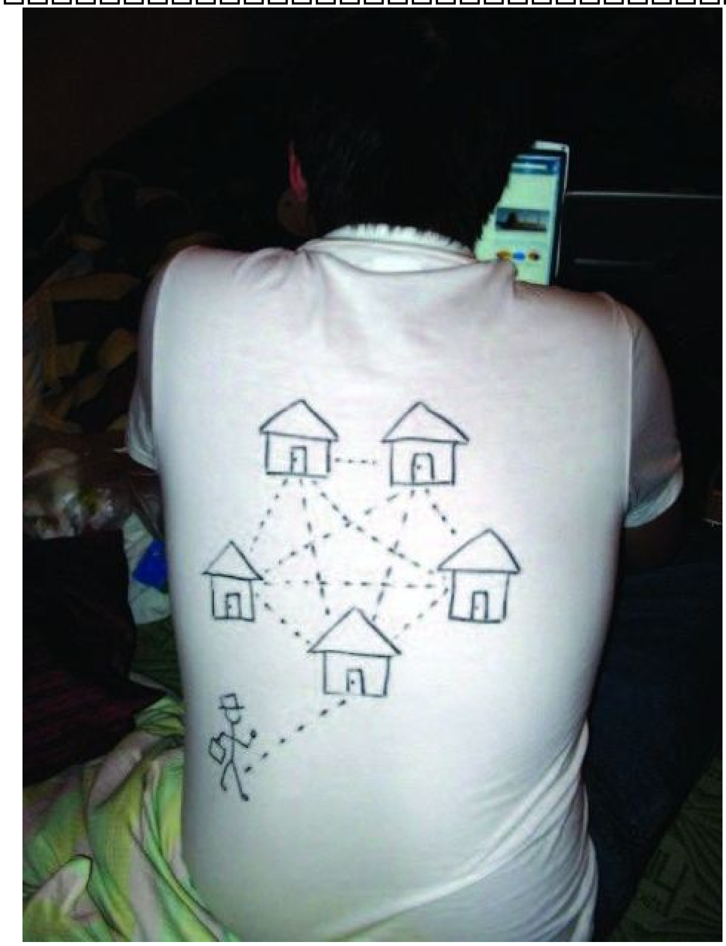


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1 Rashers Ronald□□□J. P. Donleavy□□□*The Destinies of Darcy Dancer, Gentleman*□□□□□Atlantic Monthly Press□1994□□□



□1-12 □□□1987□□W. Cook□□□□□□□□□□V. Chvátal□□□□□□□J. P. Donleavy□□□□□Adrian Bondy□□□□□□□□□□□□□□□□1987□□J. P. Donleavy□□□□□□□□□□

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> ——George Dantzig[illegible]Ray Fulkerson[illegible]Selmer Johnson[illegible]1954[illegible] [1]

1. Dantzig, Fulkerson, and Johnson (1954).

[illegible]“[illegible]”[illegible]TSP[illegible]

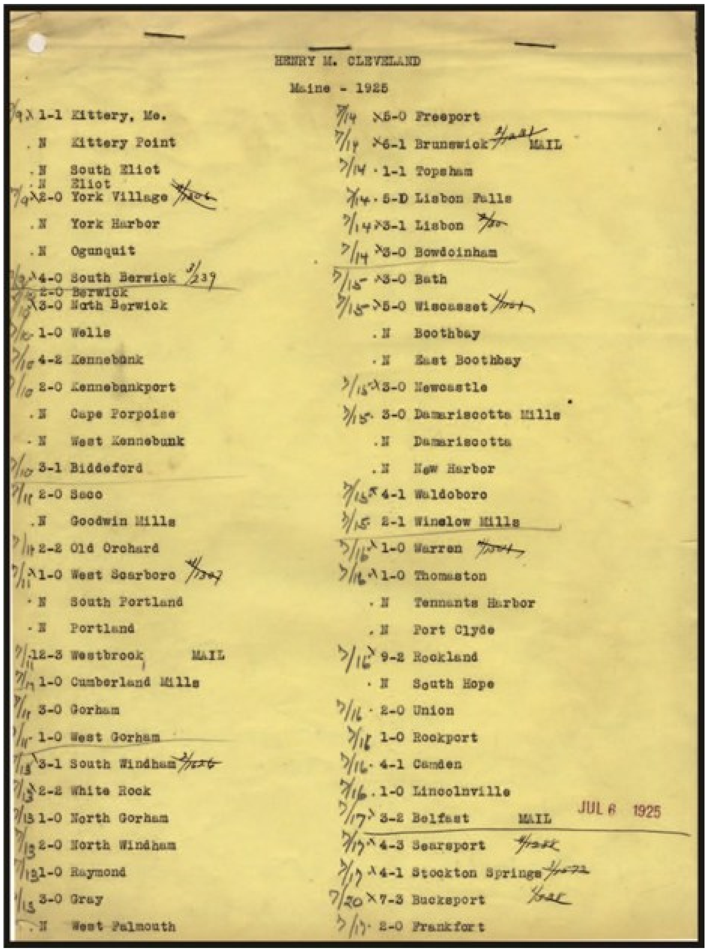
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1. [illegible]eBay[illegible]H. M. Cleveland[illegible]50[illegible]“[illegible]”[illegible]


HENRY M. CLEVELAND

Maine - 1925

1-1 Kittery, Me.
N Kittery Point
N South Eliot
N Eliot
2-0 York Village
N York Harbor
N Ogunquit
4-0 South Berwick
2-0 Berwick
3-0 North Berwick
1-0 Wells
4-2 Kennebunk
2-0 Kennebunkport
N Cape Porpoise
N West Kennebunk
3-1 Biddeford
2-0 Saco
N Goodwin Mills
2-2 Old Orchard
1-0 West Scarboro
N South Portland
N Portland
12-3 Westbrook MAIL
1-0 Cumberland Mills
3-0 Gorham
1-0 West Gorham
3-1 South Windham
2-2 White Rock
1-0 North Gorham
2-0 North Windham
1-0 Raymond
3-0 Gray
N West Falmouth

5-0 Freeport
6-1 Brunswick MAIL
1-1 Topsham
5-0 Lisbon Falls
3-1 Lisbon
3-0 Bowdoinham
3-0 Bath
5-0 Wiscasset
N Boothbay
N East Boothbay
3-0 Newcastle
3-0 Damariscotta Mills
N Damariscotta
N New Harbor
4-1 Waldoboro
2-1 Winslow Mills
1-0 Warren
1-0 Thomaston
N Tennants Harbor
N Port Clyde
9-2 Rockland
N South Hope
2-0 Union
1-0 Rockport
4-1 Camden
1-0 Lincolnville
3-2 Belfast MAIL
4-3 Searsport
4-1 Stockton Springs
7-3 Bucksport
2-0 Frankfort

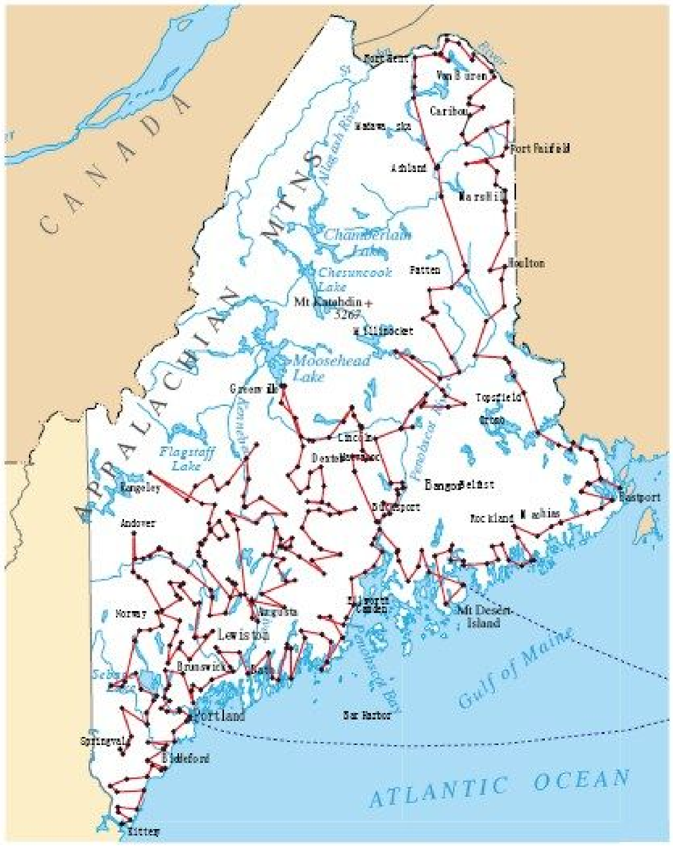
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> 1925[illegible]7[illegible]15[illegible]

[illegible]Cleveland[illegible]



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1925[illegible]Cleveland[illegible]Timonthy Spear[illegible]*100 Years on the Road: The Traveling Salesman in American Culture*[illegible]*Commercial Travelers Magazine*[illegible]1883[illegible]20[illegible]19[illegible]20[illegible]35[illegible]20[illegible]Cleveland[illegible]

Spear[illegible]L. P. Brockett[illegible]*Commercial Traveller's Guide Book*[illegible]2-3[illegible]



地图收纳柜
（兰德·麦克纳利公司供图）

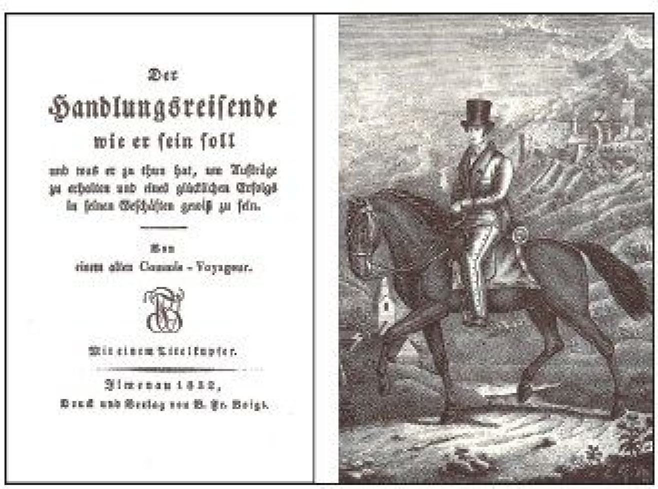
用钉绳法在地图上规划旅行商路线
（兰德·麦克纳利公司供图）

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2. *Der Handlungsreisende — wie er sein soll und was er zu thun hat, um Aufträge zu erhalten und eines glücklichen Erfolgs in seinen Geschäften gewiss zu sein — Von einem alten Commis-Voyageur.* B. Fr. Voigt, Ilmenau, 1832. □□

3. □□□□□□□Linda Cook□□□□□□□□□□□□□□□□□□□□——□□□

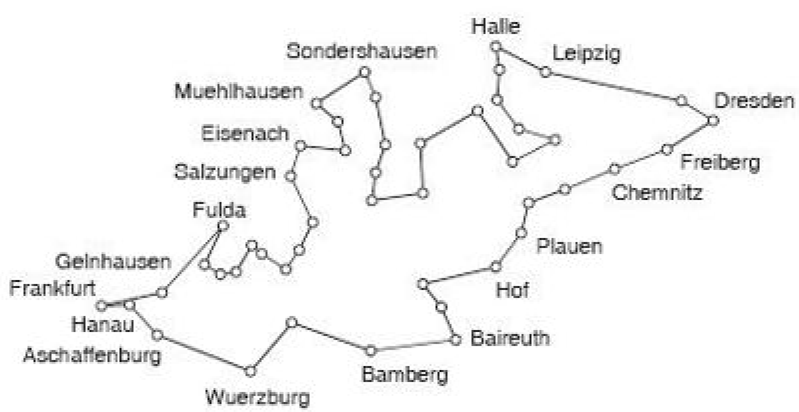


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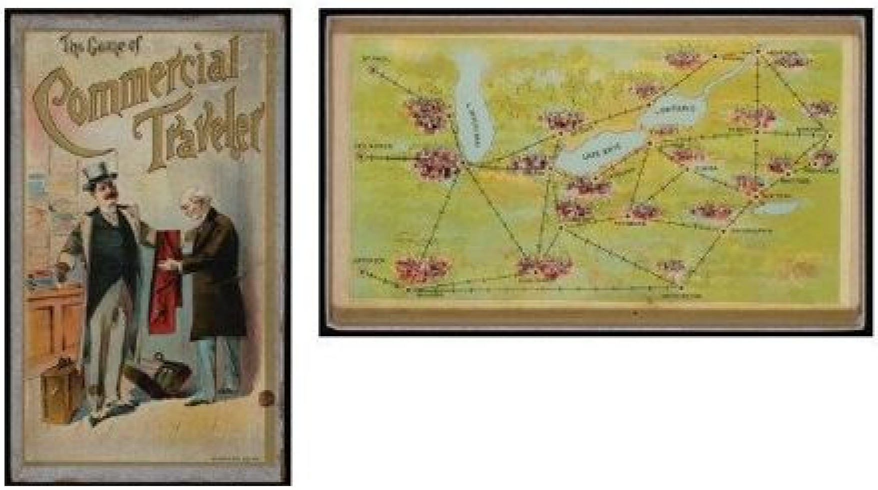
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4. □□□□□□The Drummer□□□□□□□□□□□□□□□□□Marshall, G. L. 1892. O'er Rail and Cross-ties with Gripsack. *A Compilation on the Commercial Traveler.* New York, G. W. Dillingham□

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1. Fraker, G. C. 2004. Journal of the Abraham Lincoln Association 25, 76-97.

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2.1.3 [illegible]

[illegible]18[illegible]19[illegible]·[illegible]John Wesley[illegible][1][illegible]1791[illegible]John Hampson[illegible]“[illegible]20[illegible]30[illegible]”[2][illegible]

1. [illegible]——[illegible]

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> [illegible]5000[illegible]500[illegible]
>
> ——Freeborn Garrettson[illegible]1781[illegible][3]

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> [illegible]500[illegible]63[illegible]500[illegible]
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2.2 [illegible]

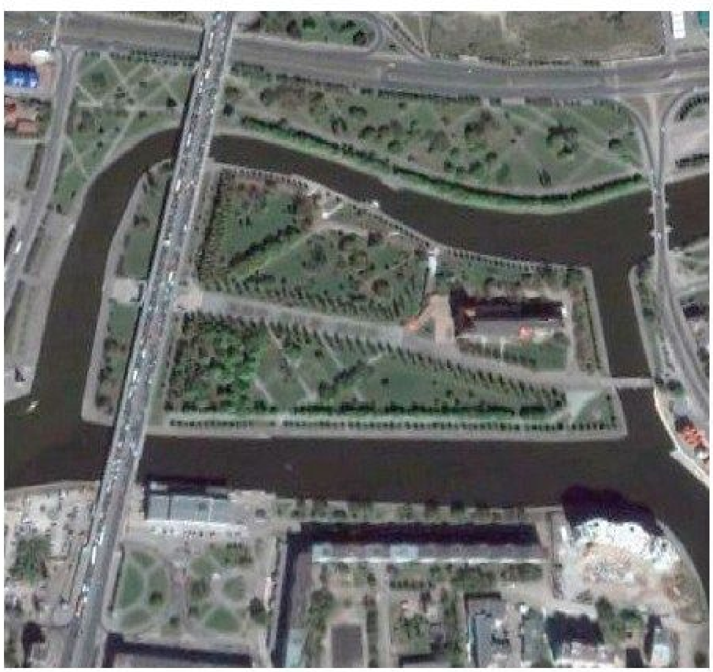
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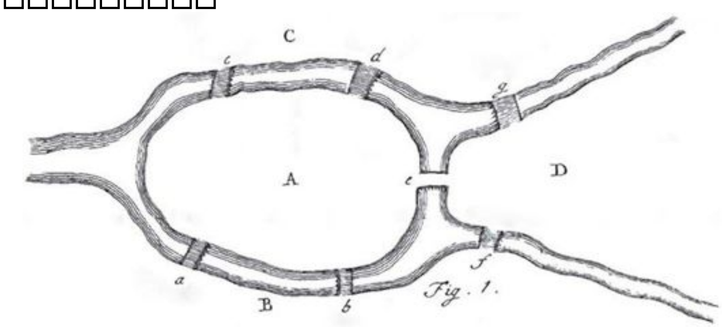
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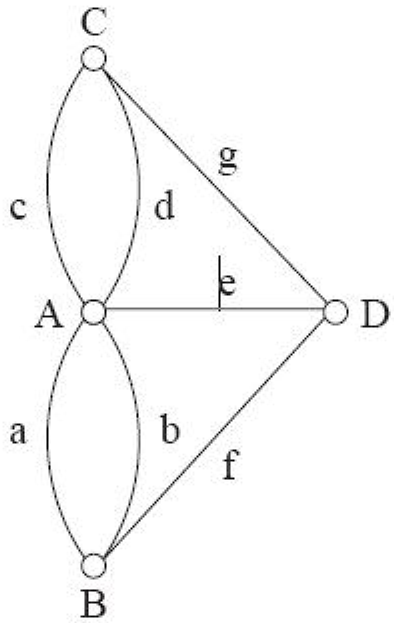


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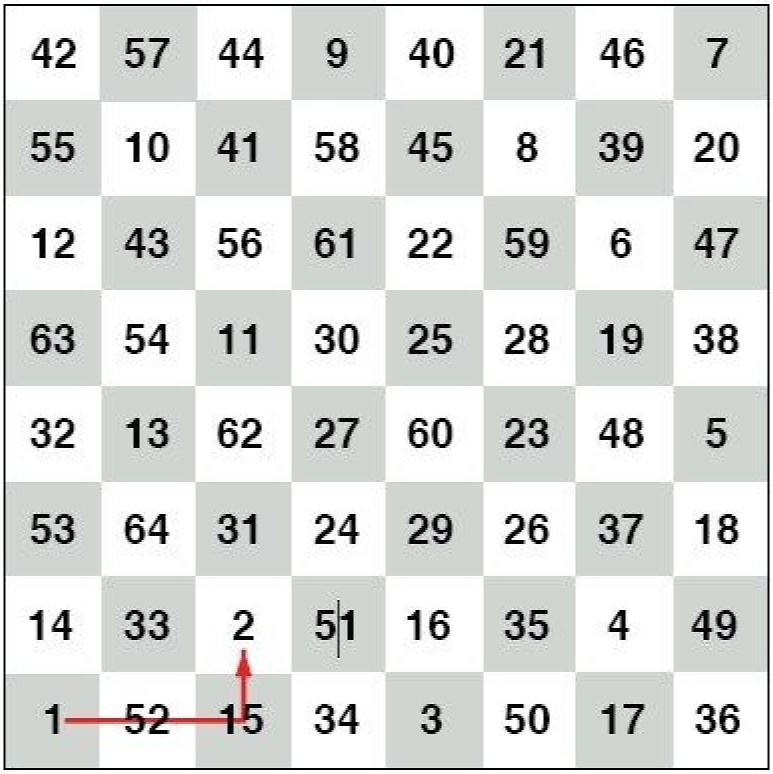
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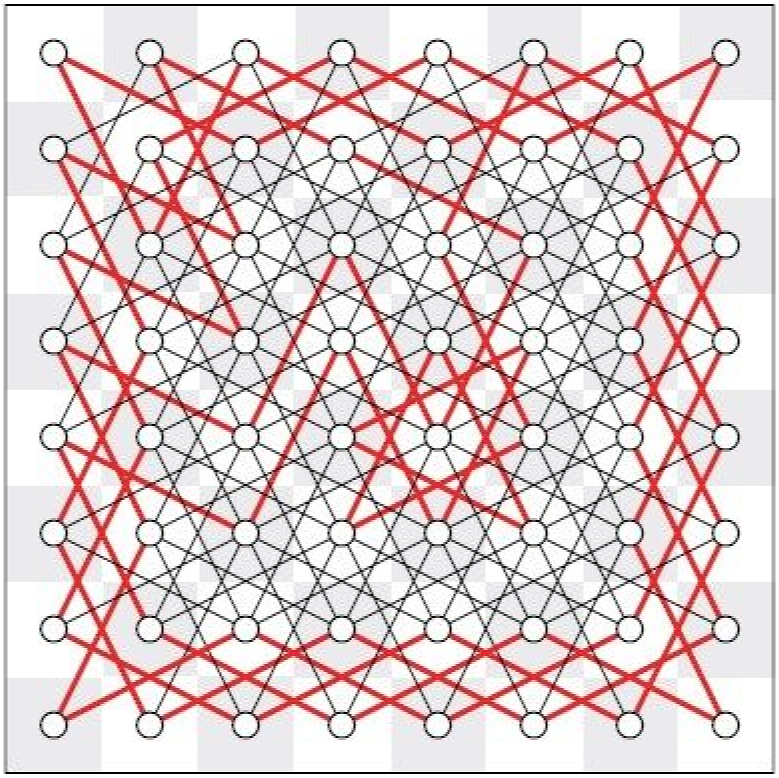
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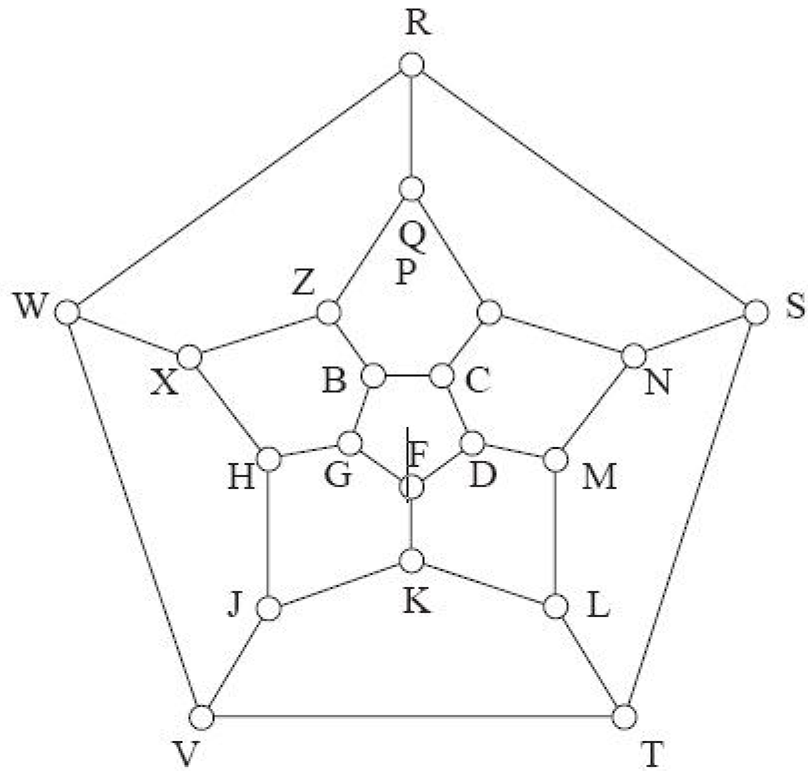
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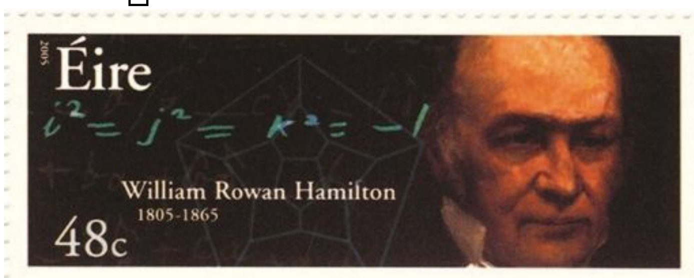
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2.2.3 Icosian□

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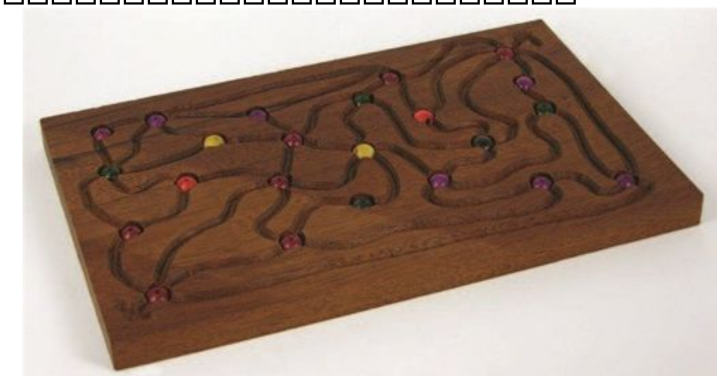
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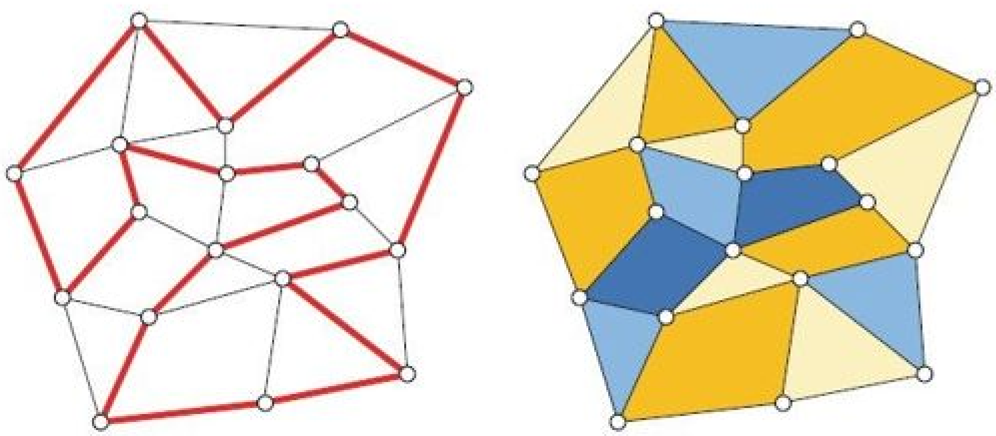
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2. “[illegible]”[illegible]Bletchley Park[illegible]——[illegible]

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3. [illegible]·[illegible]1852[illegible]10[illegible]26[illegible]Thomas L. Hankins: *Sir William Rowan Hamilton*, Johns Hopkins University Press, 1980[illegible]

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[illegible]Karl Menger[illegible]20[illegible]20[illegible]Menger[illegible] [illegible]1930[illegible]2[illegible]5[illegible]Menger[illegible]TSP[illegible][1][illegible]

1. Menger (1931).

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2. Dantzig, Fulkerson, Johnson (1954).

> [illegible]Merril Flood[illegible]1937[illegible]Flood[illegible]Albert. W. Tucker[illegible]1934[illegible]Hassler Whitney[illegible]Whitney[illegible]

Merril Flood[illegible]TSP[illegible]Whitney[illegible]1956[illegible]“[illegible]1934[illegible]Hassler Whitney[illegible]”[3][illegible]1984[illegible]Flood[illegible]Tucker[illegible]“Whitney[illegible]48[illegible]”[illegible]TSP[illegible][4]

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[illegible]Menger[illegible]Whitney[illegible]Alexander Schrijver[illegible]1930[illegible]1931[illegible]

Menger[illegible]Whitney[illegible][5][illegible]

5. Schrijver[illegible]2003[illegible]Menger[illegible]

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6. Hoffman and Wolfe (1985).

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2. Reid (1996).

Robinson□□□□□□□□□□□□□□□□□□□□□1949□□□□□TSP□□□“□□□”[3]□□□TSP□□□□□□□□□□Menger□□□□□□□□20□□□□□□□□□□□□□□□□□□□□□□□Robinson□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□5□□□□□□□□

3. Reid (1996).

TSP□□□□

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[illegible]“[illegible]”[illegible]Flood[illegible]Dantzig[illegible]

Robinson[illegible]TSP[illegible]48[illegible]“[illegible]”[illegible]“[illegible]”[illegible]Merrill Flood[illegible]Albert Tucker[illegible]“[illegible]”[illegible]20[illegible]50[illegible]“traveling salesman problem”[illegible]“travelling”[illegible]“salesman's”[illegible][1][illegible]“[illegible]”[illegible]Dantzig[illegible]

1. [illegible]“[illegible]”[illegible]“[illegible]”[illegible]“[illegible]”[illegible]——[illegible]

2.5 [illegible]

[illegible]Flood[illegible]TSP[illegible]Prasanta Chandra Mahalanobis[illegible]Mahalanobis[illegible]

2.5.1 [illegible]

Mahalanobis[illegible]*Sankhya*[illegible]TSP[illegible]

20[illegible]30[illegible][1][illegible]

1. [illegible]——[illegible]

[illegible]600[illegible]Mahalanobis[illegible]TSP[illegible]Mahalanobis[illegible]1940[illegible][2][illegible]

2. Mahalanobis (1940).

> [illegible]n[illegible][3][illegible]$\sqrt{n-1}/\sqrt{n}$[illegible]$\sqrt{n-1}/\sqrt{n}$[illegible]n[illegible]$\sqrt{n}$[illegible]n[illegible]

3. [illegible]——[illegible]

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□2-19 Prasanta Chandra Mahalanobis□□□□Mahalanobis□□□□□□□□□□□□□□□□□□□□Mahalanobis□□□□□□

2.5.2 □□□□□□□

Mahalanobis□□□□TSP□□(x, y)□□□x□y□□□□□□0□1□□TSP□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

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1. Ghosh, M. N. 1949. Calcutta Stat. Assoc. 2, 83–87.

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2.5.3 TSP□□

□□Mahalanobis□Marks□Ghosh□□□n□□□□□□□□□□□□□□□□□2-20□□□□□□□□□□□□1000□□□□□□10 000□□□□□□□□□□□□□□□□√1000□□□□□□□□□□□□□□□□□□□□□□□□□□□□0.7313□□□□□□1000□□□□□□□□□□□□□□□□□□□□□□Beardwood□Halton□Hammersley□1959□□□□□□□□□□□□□n□□□□□□□□□□□□□β□□□□□□□□[1]□β□□**TSP**□□□TSP constant□□

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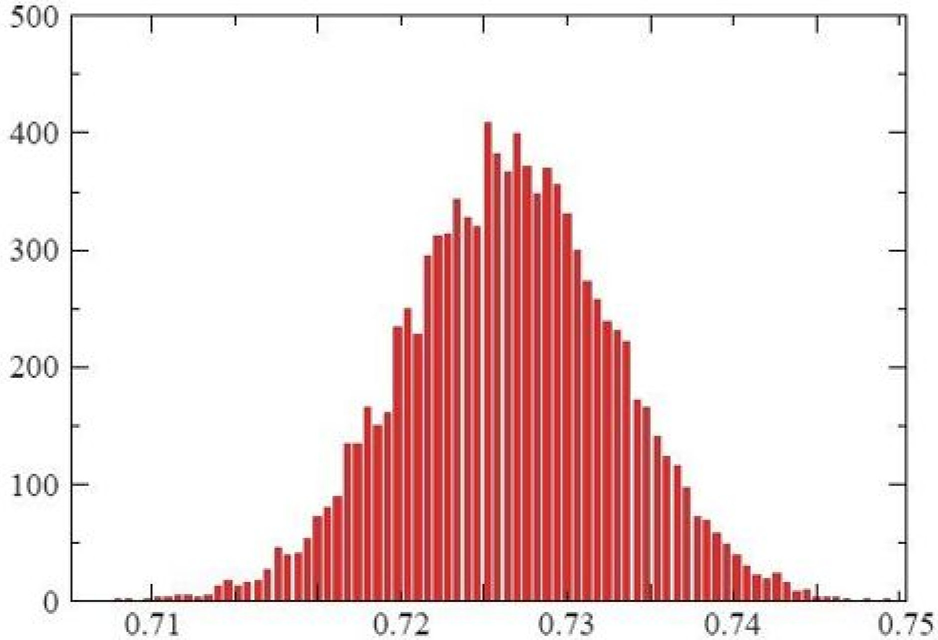
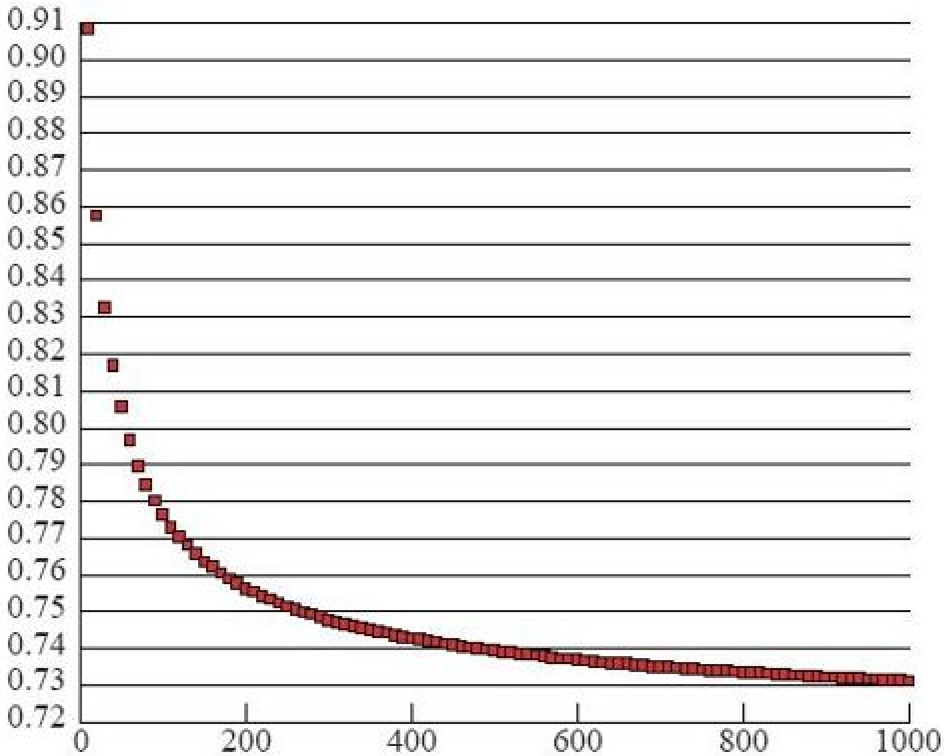


图2-20 □□1000□□□□□□10 000□□□□□□□□□

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David Applegate□David Johnson□Neil Sloane□□□□β□□□□□□□□□□□□6□□□□□TSP□□□□□Concorde□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□2-21□□□□□□n□□□□□□□□□□√n□□□□□□□□□□□□□β□□□0.712□[2]

2. □□□□□□β□□□□□□□□□□□□□□Percus, A. G., O. C. Martin. 1996. Phys. Rev. Let. 76, 1188–1191.


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> [illegible]

——George Dantzig[illegible]1986[illegible][1]

1. Albers, Reid (1986).

[illegible]·[illegible]·[illegible]“[illegible]”[illegible]“The Mathematician”[illegible]TSP[illegible]TSP[illegible]

3.1 [illegible]

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3.1.1 [illegible]

[illegible]GPS[illegible]GPS[illegible]TSP[illegible]GPS[illegible]TSP[illegible]

[illegible]Alain Kornhauser[illegible]GPS[illegible]GPS[illegible]GPS[illegible]

3.1.2 [illegible]

[illegible]TSP[illegible]Merrill Flood[illegible]TSP[illegible]George Morton[illegible]Ailsa Land[illegible]TSP[illegible]Rapidis[illegible]Concorde[illegible]Forbruger-Kontakt[illegible]Rapidis[illegible]3-1[illegible]



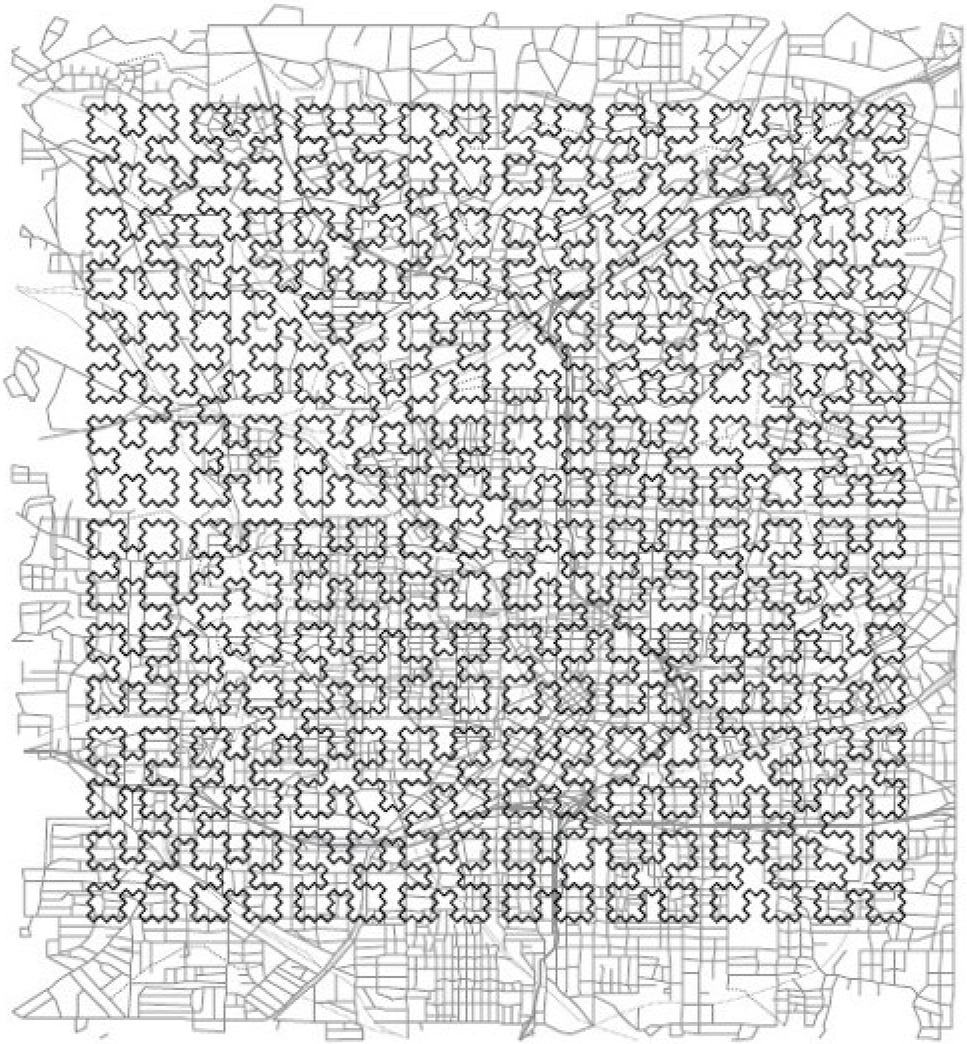
□3-1   Forbruger-Kontakt□□□□□TSP□□□Thomas Isrealsen□□□

3.1.3 □□□□

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1 “□□□□”□□□Bartholdi III, J. J., et al. 1983. Interfaces 13, No. 3, 1-8.

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[illegible]3-2 [illegible]John Bartholdi[illegible]

3.1.4 [illegible]

TSP[illegible]Mahalanobis[illegible]20[illegible]30[illegible]William Pulleyblank[illegible]47[illegible]TSP[illegible]200[illegible]TSP[illegible]

3.1.5 [illegible]

[illegible]*The Death of Vishnu*[illegible]Manil Suri[illegible]*SIAM News*[illegible][1][illegible]

1 Suri, M. 2001. SIAM News 34, p. 1.

> [illegible]2001[illegible]1[illegible]24[illegible]13[illegible]

[illegible]Suri[illegible]TSP[illegible]

3.1.6 “[illegible]”

[illegible] “[illegible]”[illegible]Extra Miler Club[illegible]“[illegible]”[1][illegible]3100[illegible]TSP[illegible]

1 [illegible]“[illegible]”[illegible]extra mile[illegible]“[illegible]”——[illegible]

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2 Dosher, M. *Wall Street Journal*, 1998-02-09, B1.

3.1.7 [illegible]

“[illegible]”[illegible]Iron Butt Association[illegible]35 000[illegible]“[illegible]”[illegible]“48/10[illegible]”[illegible]10[illegible]48[illegible]2009[illegible]2[illegible]Maura Gatensby[illegible]Dantzig-Fulkerson-Johnson[illegible]TSP[illegible]

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[illegible]

Gatensby[illegible]“10[illegible]48[illegible]”[illegible]6967[illegible]11 212[illegible]TSP[illegible]48[illegible]

3.1.8 [illegible]

Ron Schreck[illegible]RV-8[illegible]“Miss Izzy”[illegible]2007[illegible]109[illegible]Concorde[illegible]7[illegible]4[illegible]1991[illegible]3204[illegible]17[illegible]9[illegible]“[illegible]”[illegible]



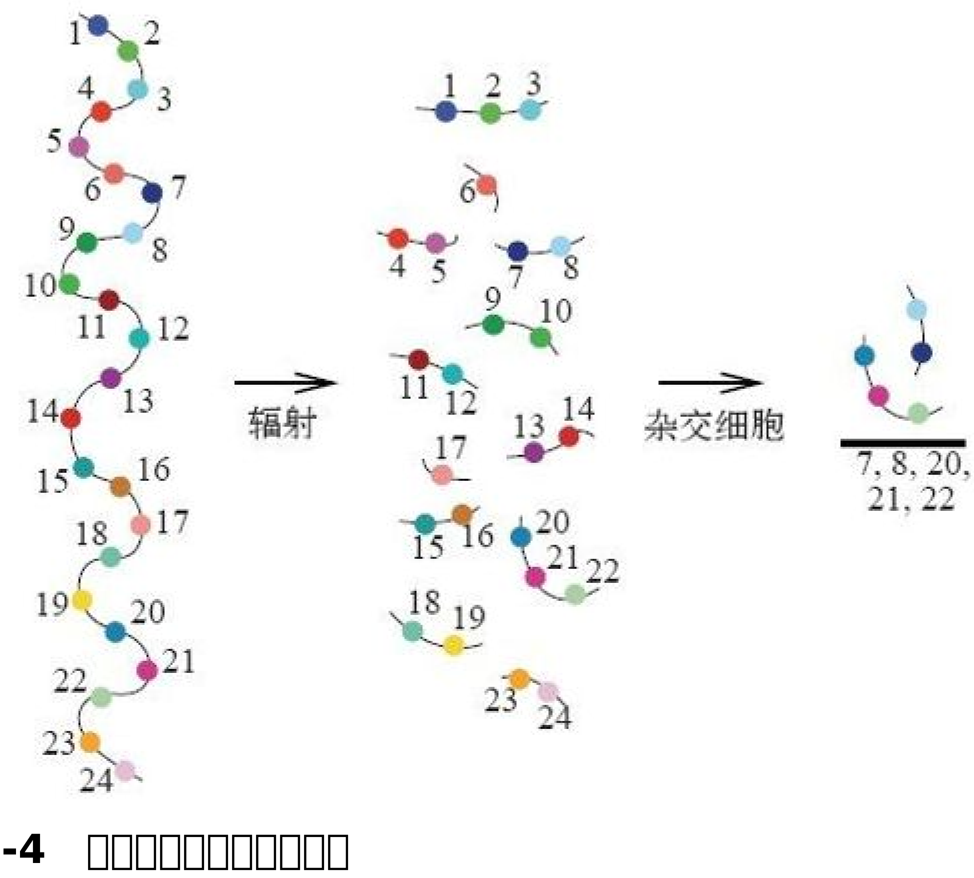
[illegible]3-3 [illegible]Miss Izzy[illegible]Ron Schreck[illegible]

3.2 [illegible]

[illegible]TSP[illegible]TSP[illegible]

[illegible]DNA[illegible]TSP[illegible]

[illegible]radiation hybrid mapping[illegible]RH[illegible]X[illegible]3-4[illegible]



[illegible]3-4 [illegible]

RH[illegible]A[illegible]B[illegible]

[illegible]A[illegible]B[illegible]A[illegible]B[illegible]
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[illegible]National Institutes of Health[illegible]Richa Agarwala[illegible]Alejandro Schäffer[illegible]
[illegible]TSP[illegible][1]
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1. Agarwala, R., et al. 2000. Genome Research 10, 350–364.

3.3 [illegible]X[illegible]

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Shawn Carlson[illegible]TSP[illegible]
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[illegible]”[1][illegible]
[illegible]TSP[illegible]

1. Carlson, S. 1997. Sci. Am. 276, 121–24.

3.3.1 [illegible]

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Martin Lu[illegible]TSP——traveling planet-finder problem[illegible]
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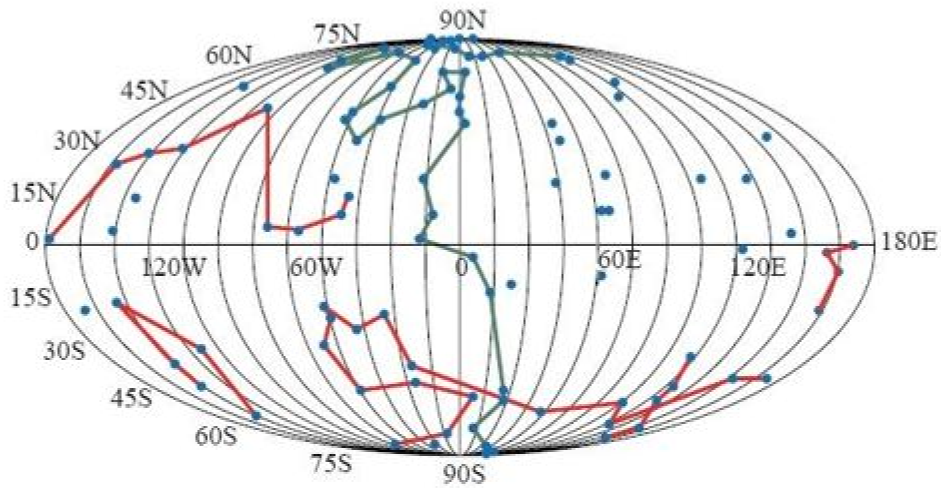
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1. Kolemen, E., N. J. Kasdin. 2007. Adv. Astronaut. Sci. 128, 215–133.



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3.3.2 X□□□□□

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1 Bland, R. G., D. F. Shallcross. 1989. Op. Res. Let. 8, 125–228.

3.3.3 □□□□□□□□□

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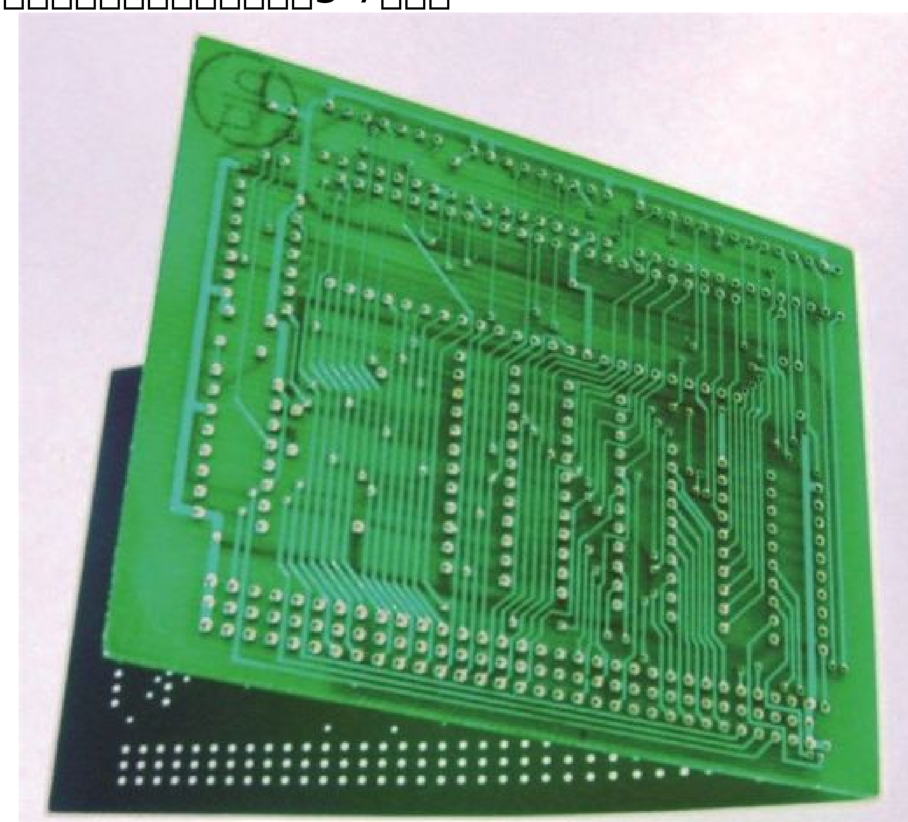
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3.4 [illegible]

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3.4.1 [illegible]

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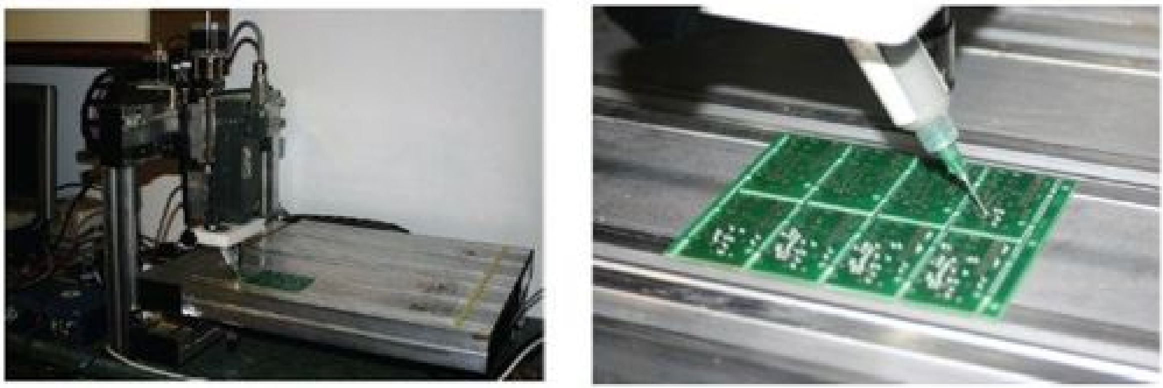
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1. Grötschel, M., M. Jünger, G. Reinelt. 1991. Zeit. Op. Res. 35, 61–84.

3.4.2 [illegible]

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[illegible]3-8 [illegible]Wladimir Nickel[illegible]

3.4.3 [illegible]

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3.4.5 [illegible]

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1. Lenstra, J. K. 1974. Operations Research 22, 413–414.

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2. Climer, S., W. Zhang. 2006. J. Mach. Learn. Res. 7, 919–943.

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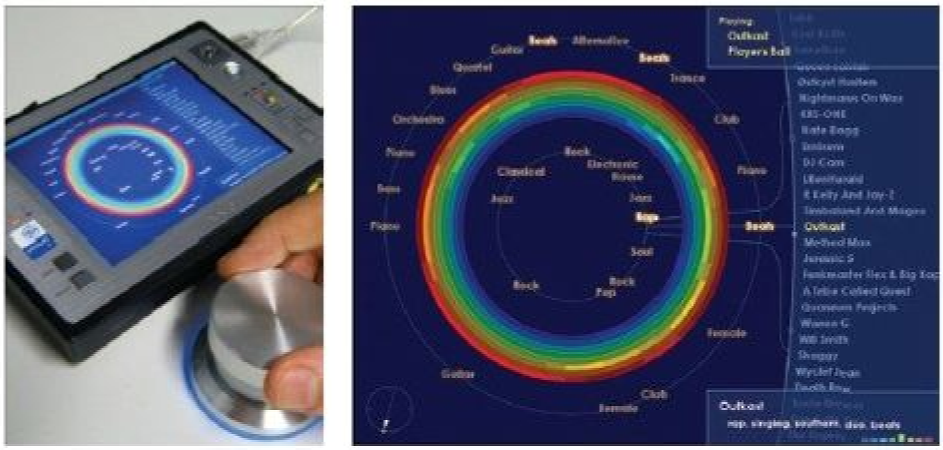


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□3-10 MusicRainbow□□□Elias Pampalk□□□

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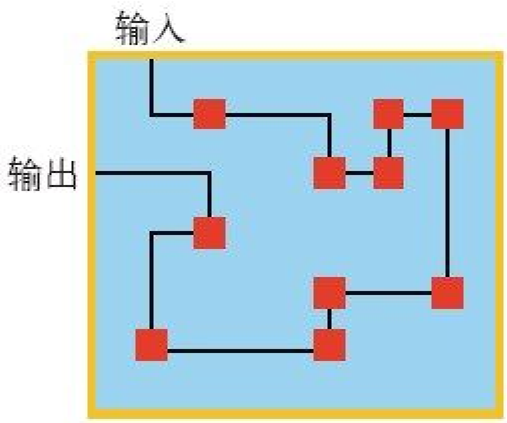
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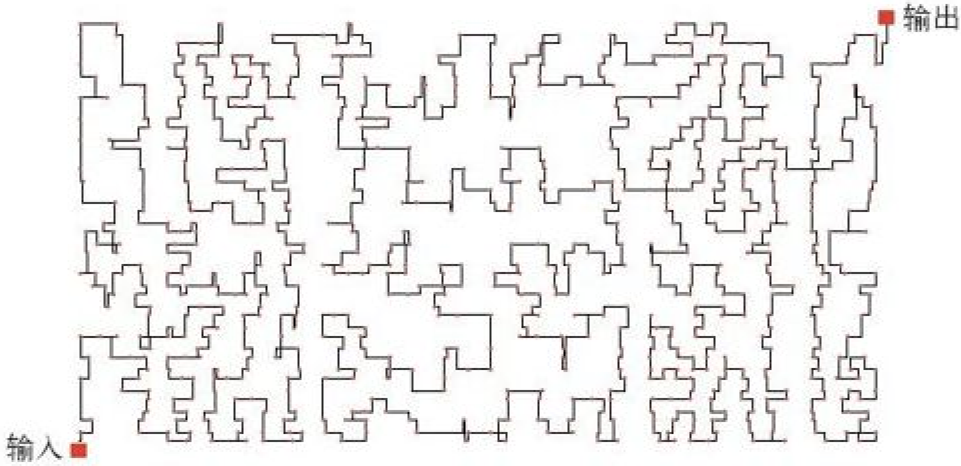
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1954[illegible]Merrill Flood[illegible]TSP[illegible]i[illegible]j[illegible]j[illegible]i[illegible]TSP[illegible]

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1. [illegible]Applegate et al. (2006), Section 2.7.

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——Robert Karg[illegible]Gerald Thompson[illegible]1964[illegible][1]

1. Karg, R. L., G. L. Thompson. 1964. Management Science 10, 225–248.

[illegible]TSP[illegible]TSP[illegible]simulated annealing[illegible]genetic algorithm[illegible]local search[illegible]TSP[illegible]

4.1 □□48□□□

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1. Dantzig et al. (1954).



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3. Dantzig et al. (1954).

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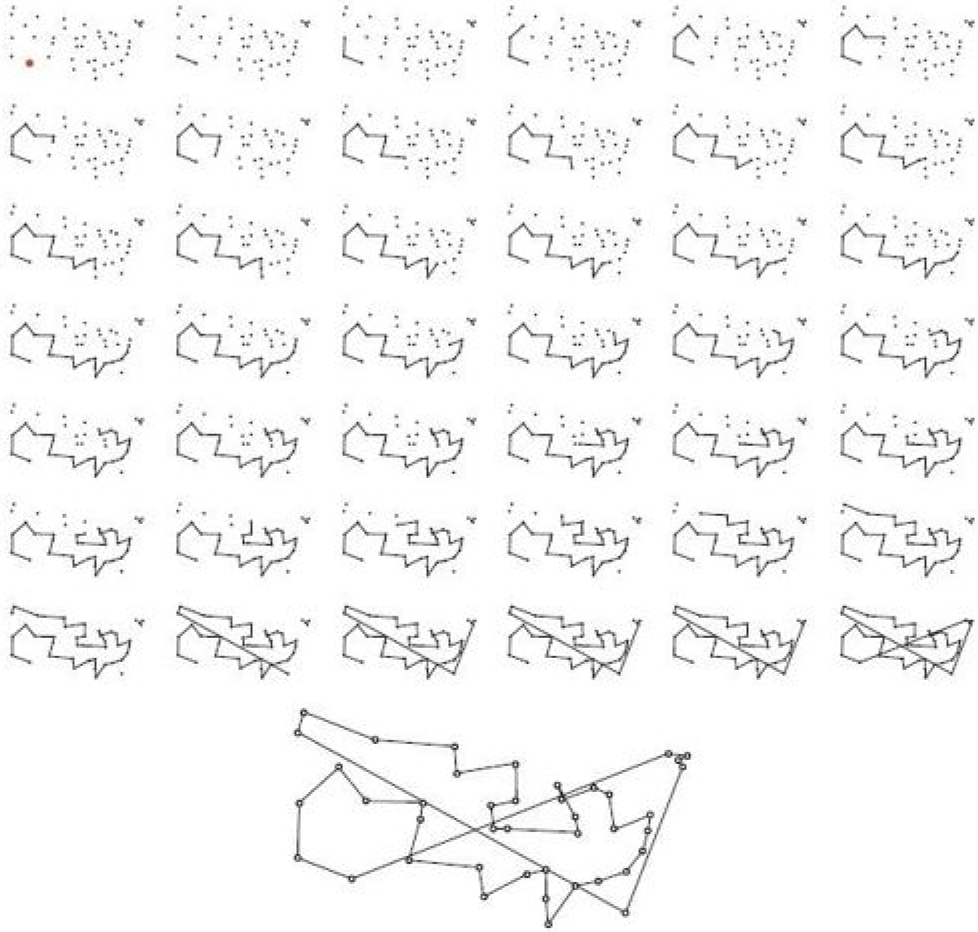
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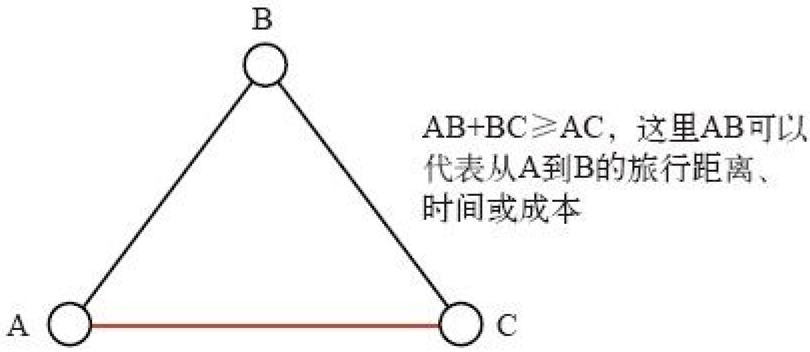


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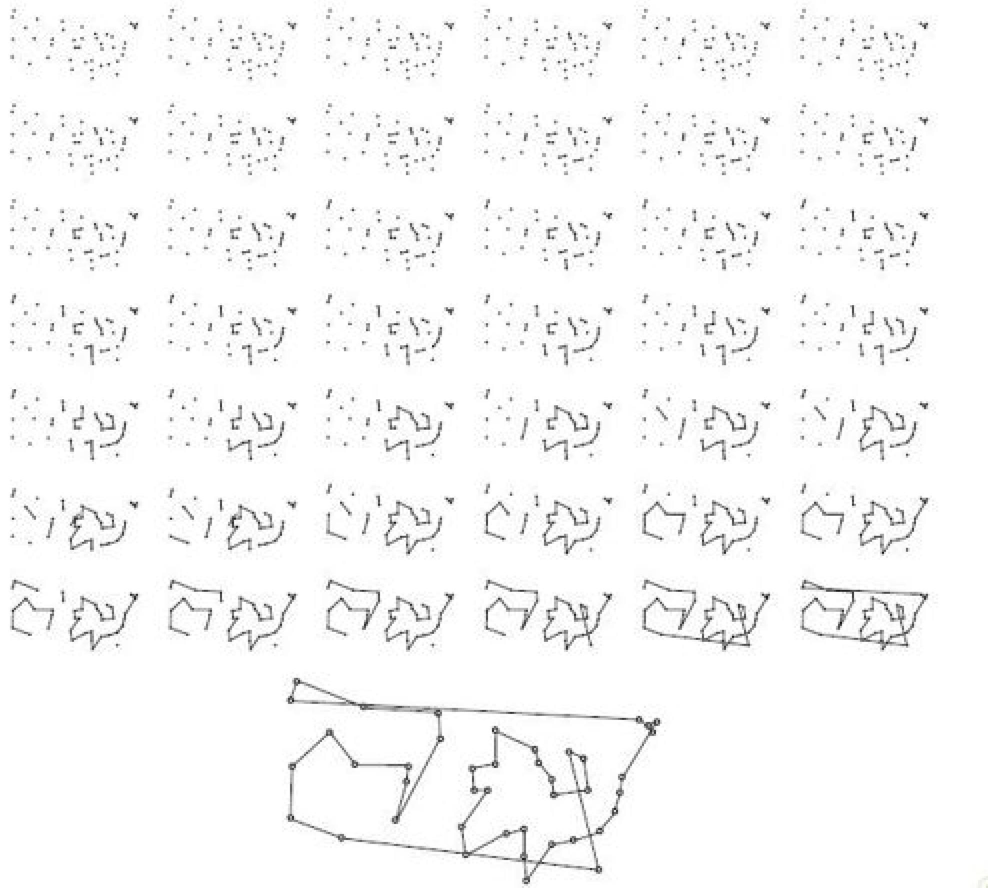
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4.2.3 [illegible]

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[illegible]John Robacker[illegible]TSP[illegible]Dantzig[illegible]9[illegible][1]

1. Robacker, J. T. 1955. RAND Research Memorandum RM-1521.

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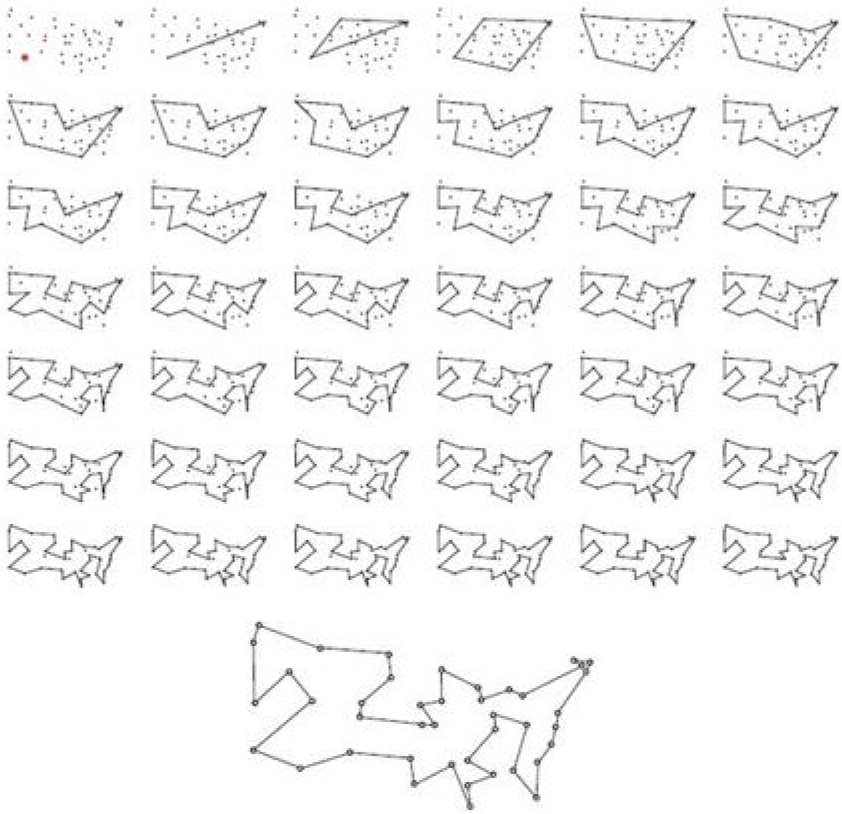
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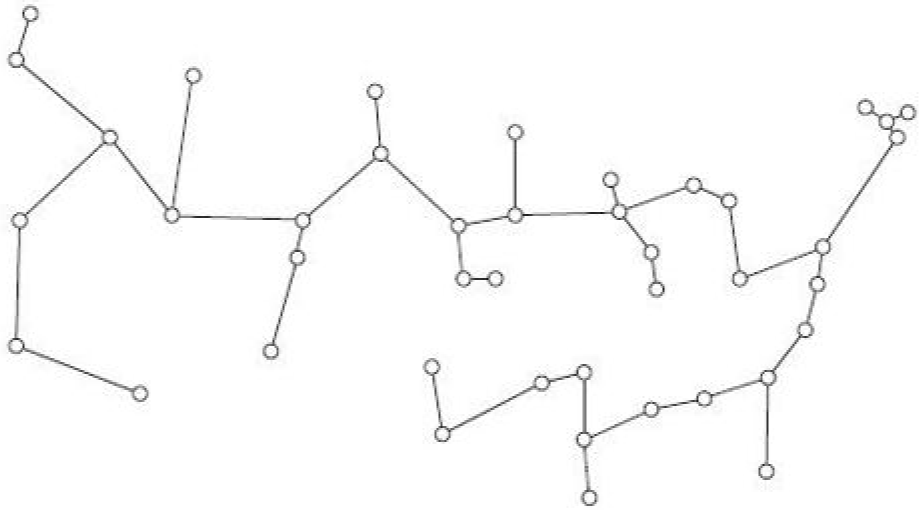
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3. Rosenkrantz, D., et al. 1977. SIAM J. Computing 6, 563–581.

4.2.4 [illegible]

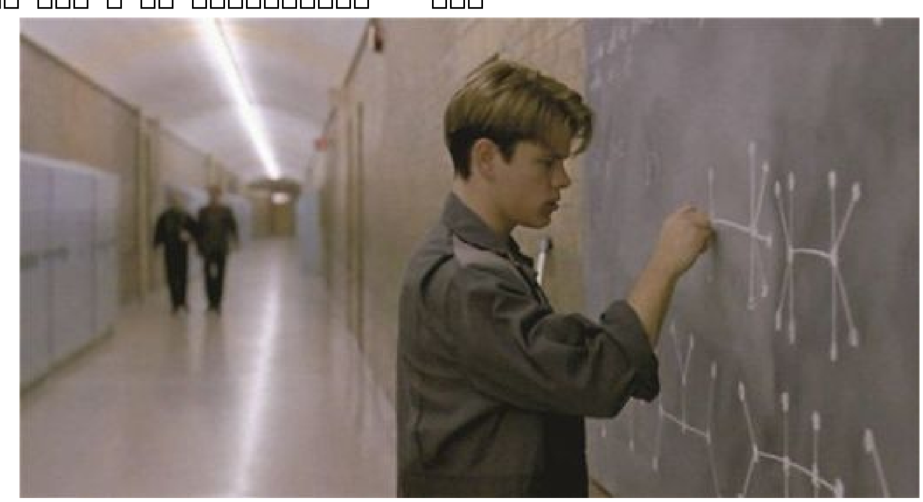
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1. Cayley, A. 1881. Am. J. Math 4, 266–268. □□□“In a tree of N knots, selecting any knot at pleasure as a root, the tree may be regarded as springing from this root, and it is then called a root-tree”□□□“knot”□“□□”□“□□□□”□□□□□“root”□□“□□□”□“□□”□□□□□□□□□□——□□□



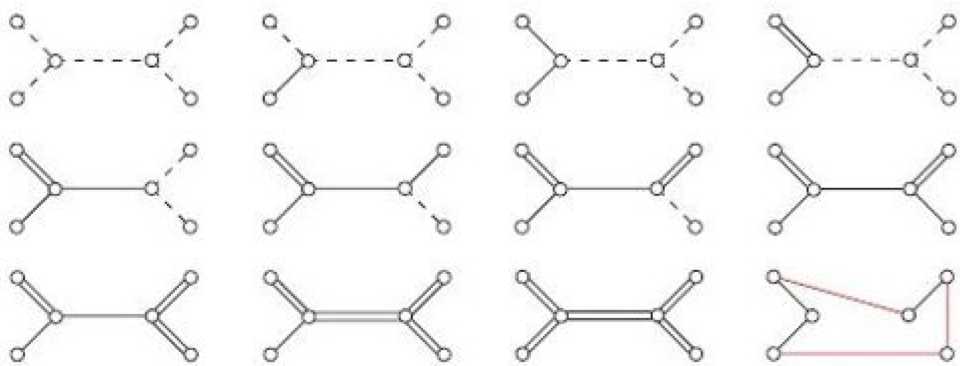
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2. Kruskal, J. 1957. Proc. Am. Math. Soc. 7, 48–50.

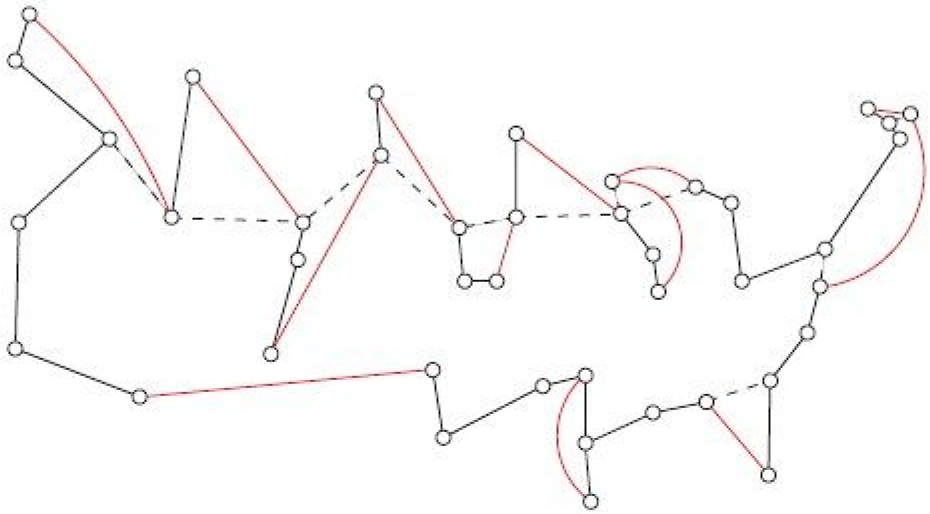
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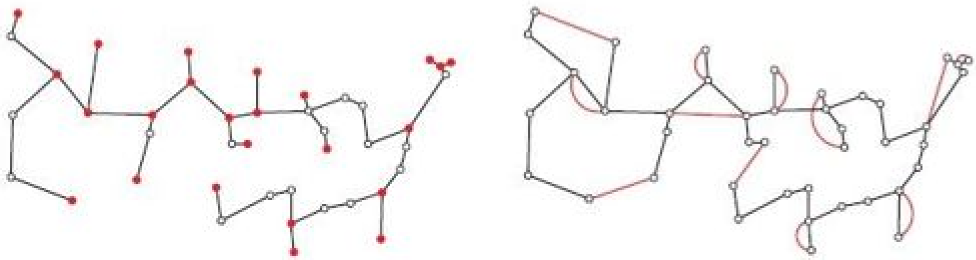
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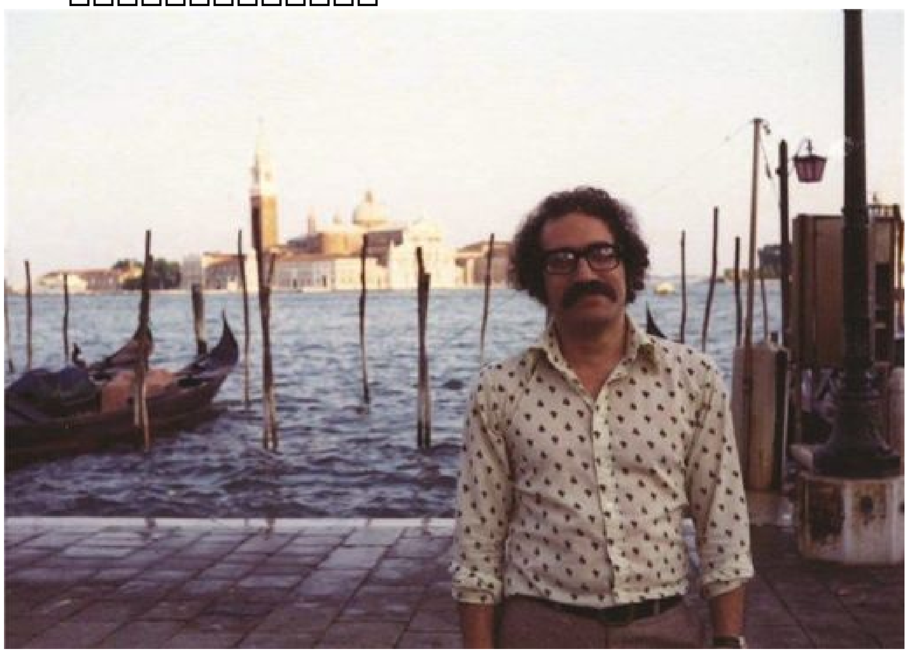
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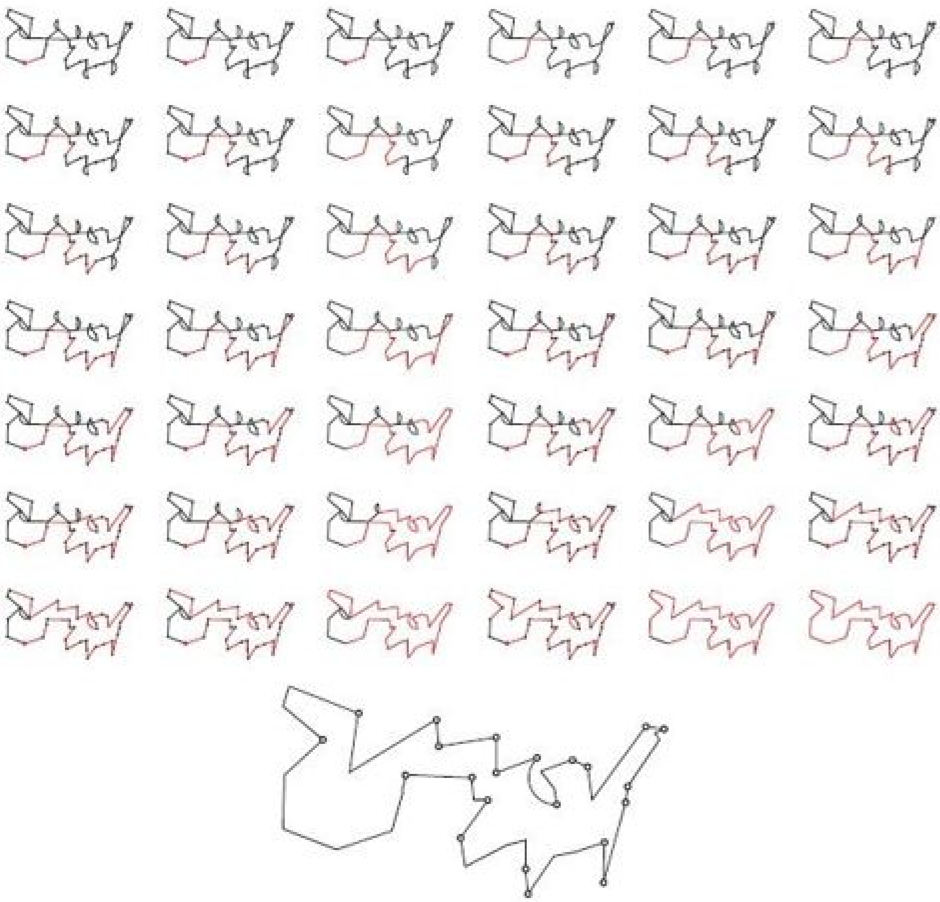
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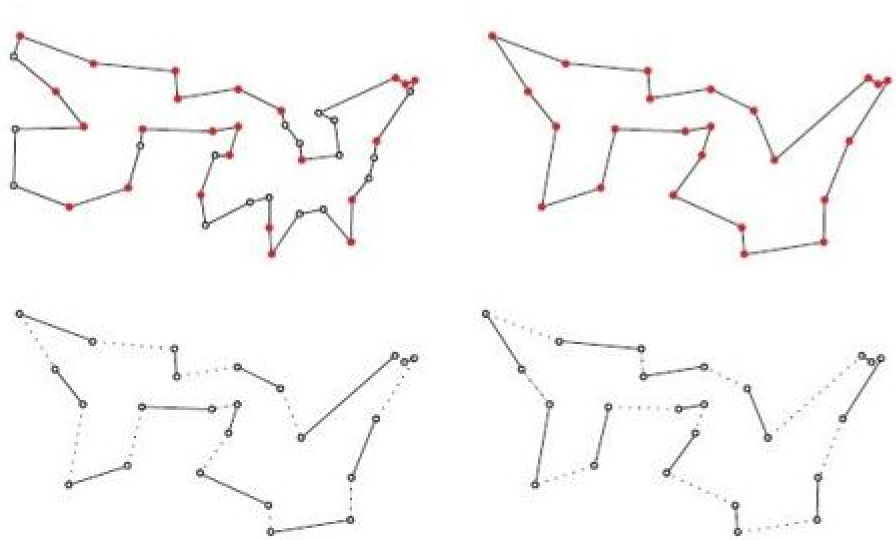


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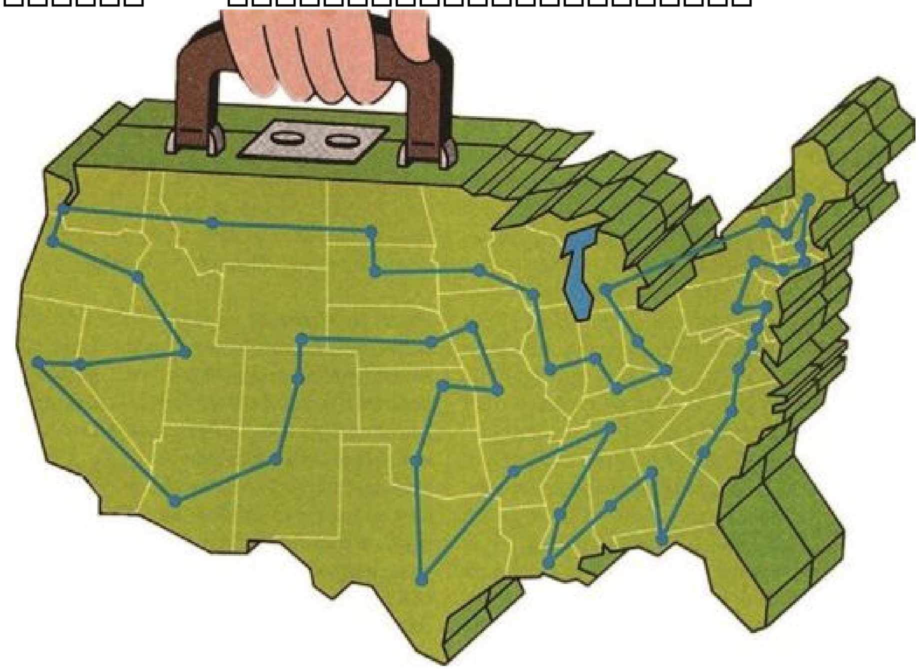
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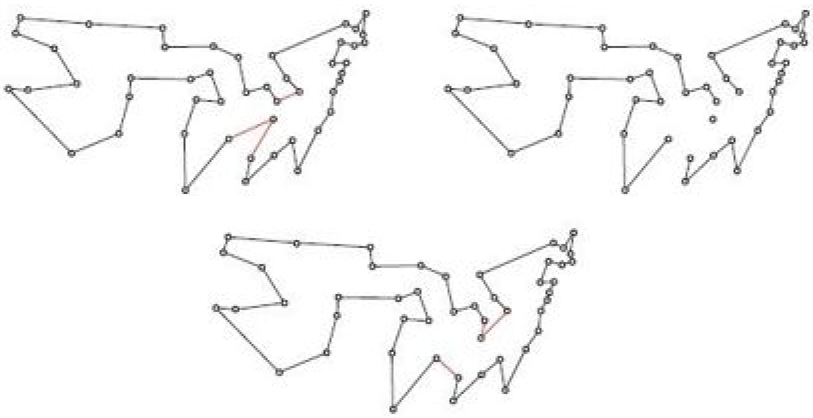
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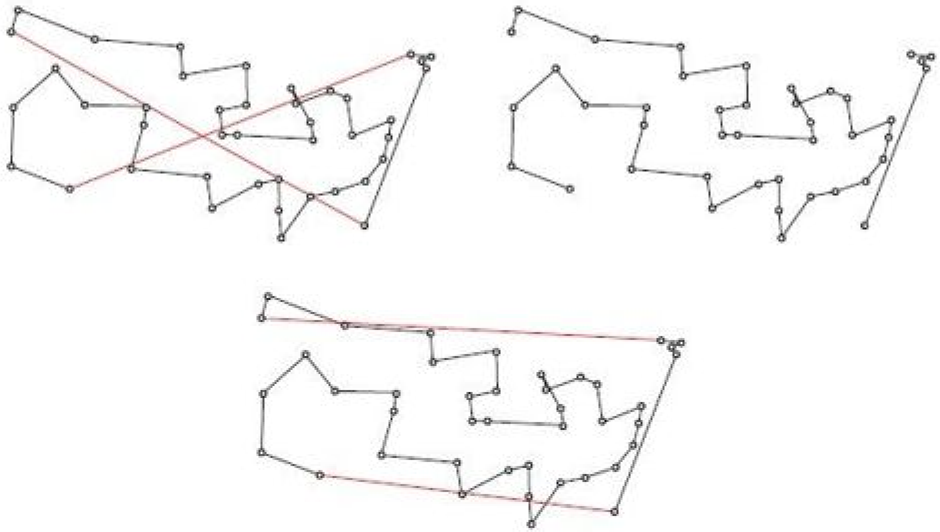
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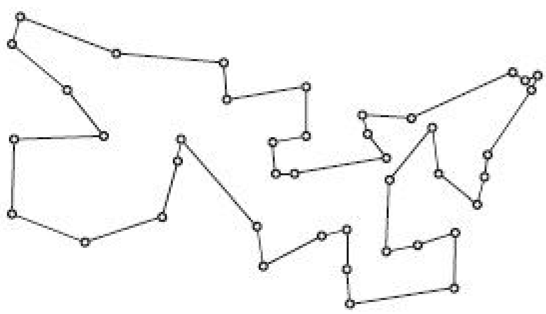
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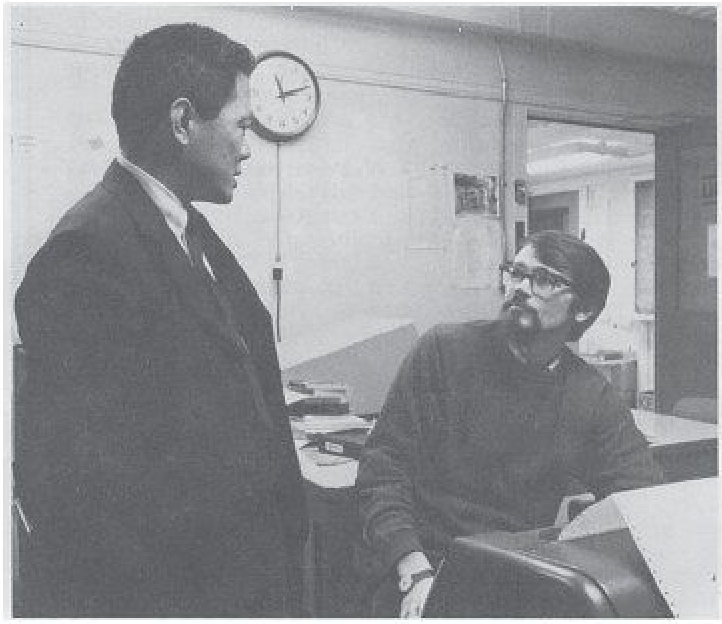


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“我想我们搞定了。” Shen Lin（左）似乎如此向 Brian Kernighan（右）表示。这两位贝尔实验室的数学家兼计算机专家发明了旅行商问题的一种高效新解法。

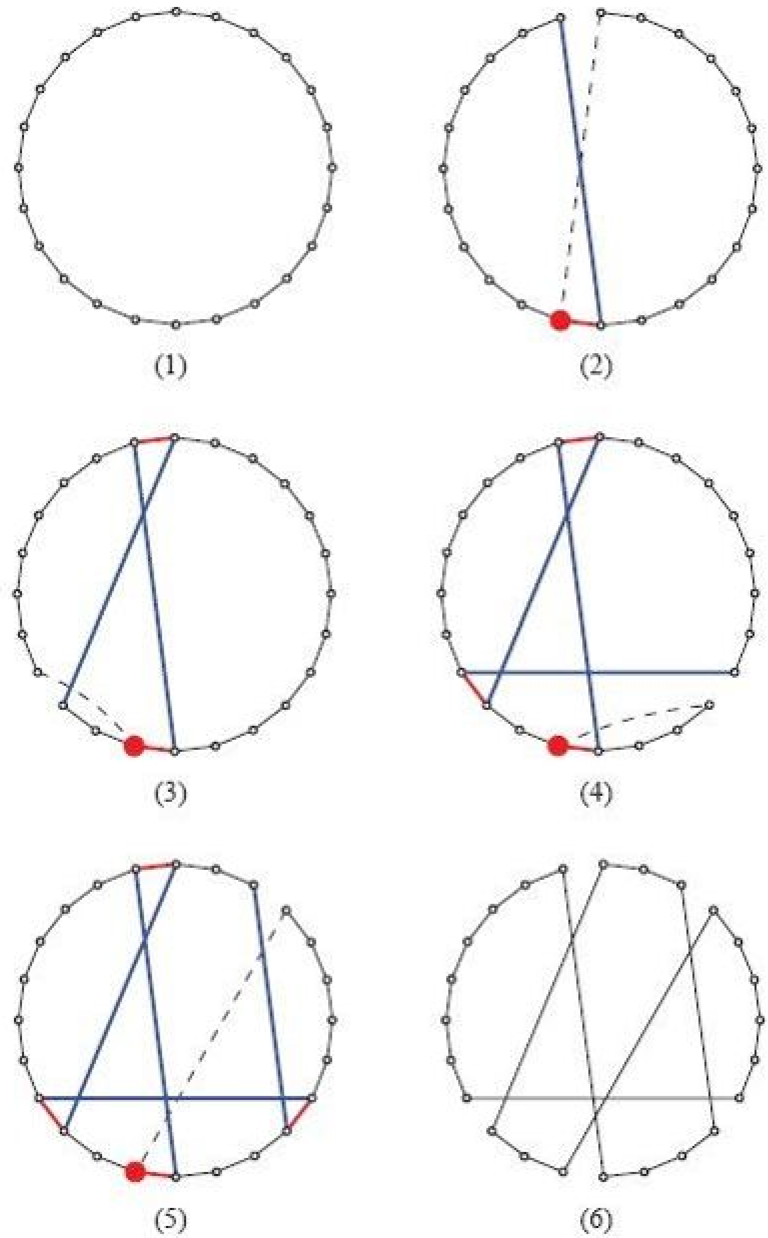
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4.3.2 Lin-Kernighan□□

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1. Lin and Kernighan (1973).

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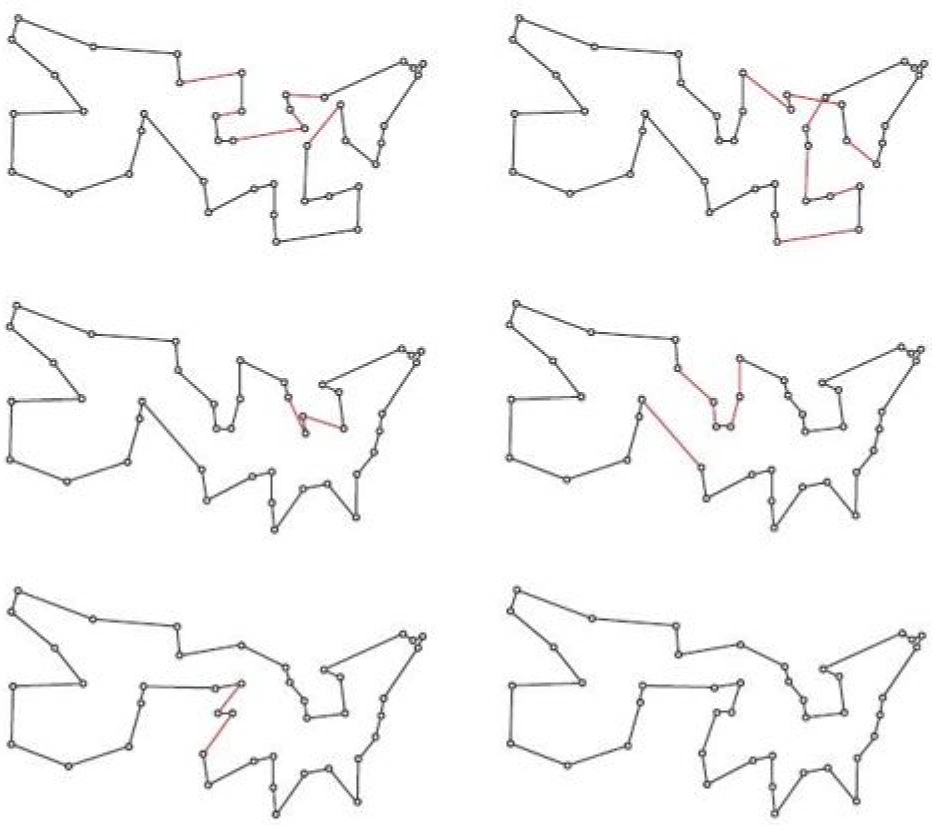
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2. Lin and Kernighan (1973).

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4.3.3 Lin-Kernighan-Helsgaun[illegible]

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1. Helsgaun, K. 2000. Eur. J. Oper. Res. 126, 106–130.

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1. Kirkpatrick, G., C. D. Gelatt, M. P. Vecchi. 1983. Science 220, 671–680.

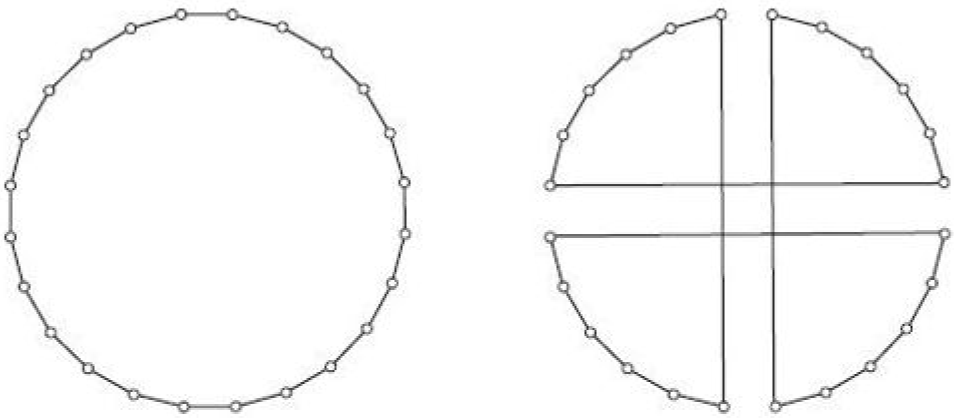
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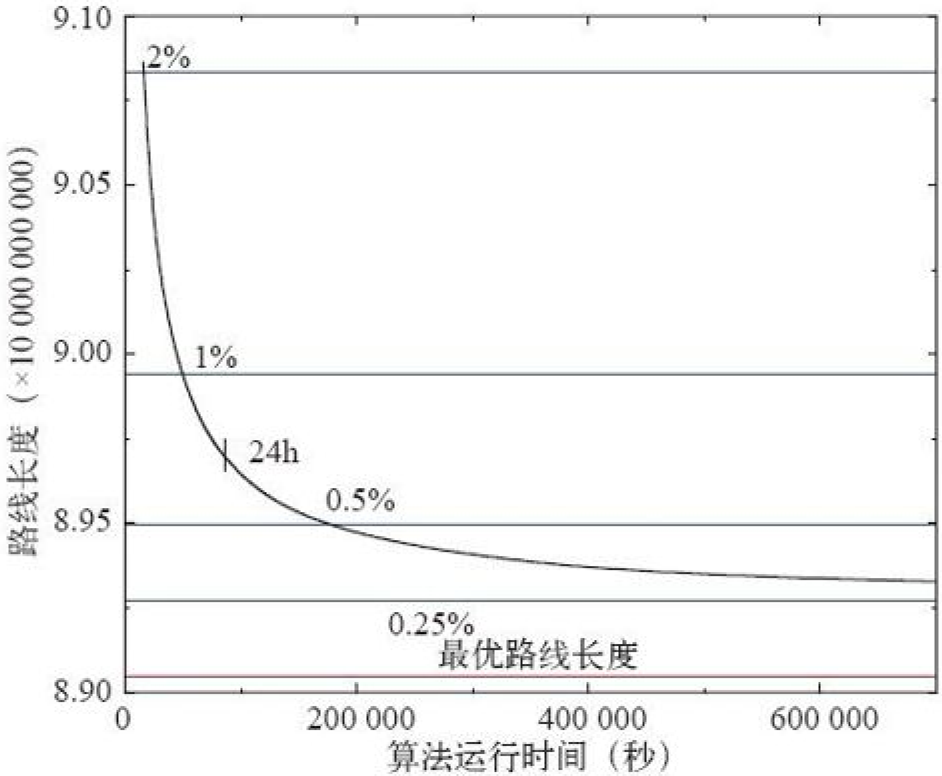


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□□genetic algorithm□□□□□□□John Holland□□□1975□□□□□□□*Adaptation in Natural and Artificial Systems*□□□□□□□□□□□□□□□[1]Holland□□□□□□TSP□□□□□□□□□□□□□□□□□□□□□□

1. Hollan, J. 1975. *Adaptation in Natural and Artificial Systems*. University of Michigan Press, Ann Arbor, Michigan.

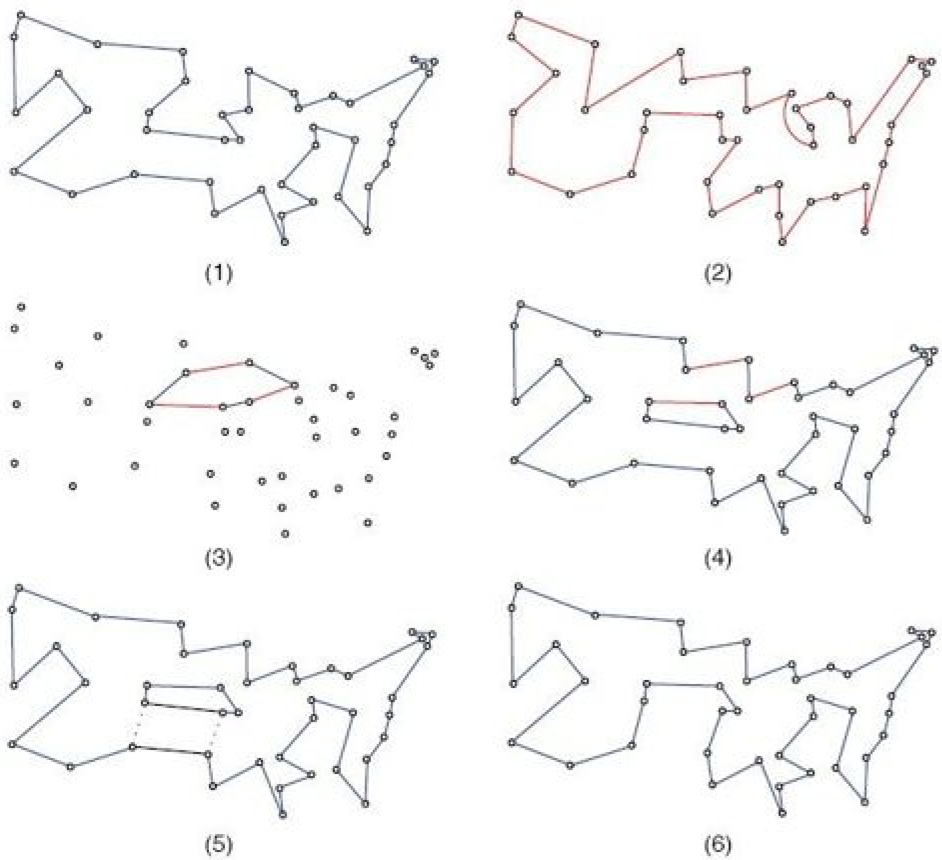
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[illegible]EAX[illegible][3][illegible]EAX[illegible]100 000[illegible]TSP[illegible]

3. Nagata, Y. 2006. Lect. Notes Comput. Sci. 4193, 372–381.

4.4.5 [illegible]

[illegible]TSP[illegible]ant-colony optimization[illegible]ACO[illegible]

[illegible]Marco Dorigo[illegible]1992[illegible][1][illegible]pheromone value[illegible]

1. http://www.aco-metaheuristic.org.



[illegible]4-28 [illegible]TSP[illegible]Günter Wallner[illegible]Georg Glaeser[illegible]Konrad Polthier[illegible]*Bilder der Mathematik*[illegible]

[illegible]LK[illegible]ACO[illegible]

4.4.6 [illegible]

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4.5 DIMACS□□□

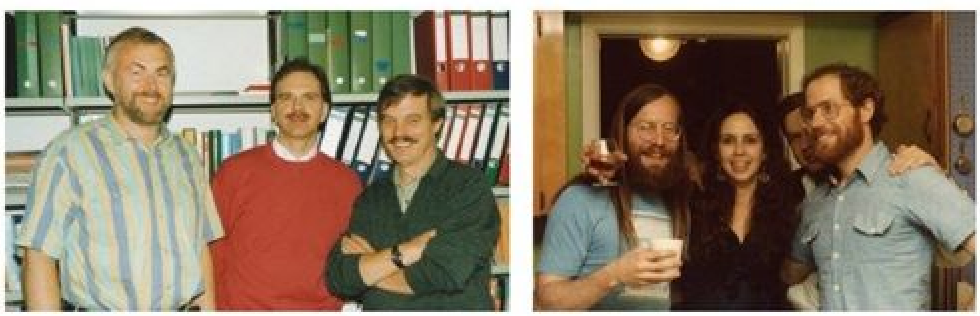
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1. http://comopt.ifi.uni-heidelberg.de/software/TSPLIB95/.

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2. http://www2.research.att.com/~dsj/chtsp/about.html.



□4-29 □□□Martin Grötschel□Gerhard Reinelt□Manfred Padberg□□□□Robert Tarjan□Dorothy Johnson□Al Aho□David Johnson

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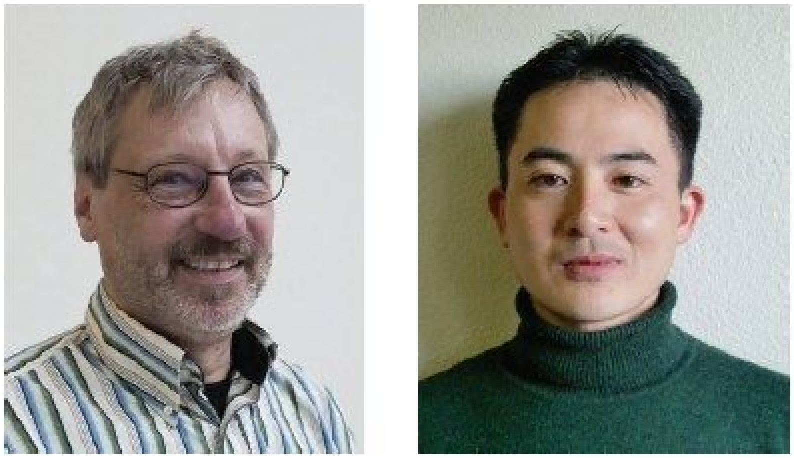
Johnson[illegible]Lyle McGeogh[illegible][3]

3. Johnson, D. S., L. A. McGeogh. 2002. In: G. Gutin, A. Punnen, eds. *The Traveling Salesman Problem and Its Variations*. Kluwer, Boston, MA. 369–443.

Johnson[illegible]2010[illegible]Knuth Prize[illegible]TSP[illegible]

4.6 [illegible]

[illegible]



[illegible]4-30 Keld Helsgaun[illegible]

[illegible]Keld Helsgaun[illegible] Helsgaun[illegible]LKH[illegible]1998[illegible]85 900[illegible] TSP[illegible]VLSI Test Collection[illegible][1][illegible]TSP[illegible]TSP[illegible]National TSP Collection[illegible][2][illegible]

1. http://www.tsp.gatech.edu/vlsi/index.html.
2. http://www.tsp.gatech.edu/world/countries.html.

[illegible]5[illegible] [illegible]

> [illegible]20[illegible]

——Martin Grötschel[illegible]2006[illegible][1]

1. Grötschel, M. 2006. Notes for a Berlin Mathematical School.

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[illegible]linear programming[illegible]
[illegible]“[illegible]X”[illegible]X[illegible]
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5.1 □□□□

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1. Albers and Reid (1986).

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2. Dantzig (1991).

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1. Carroll, L. 1865. *Alice's Adventures in Wonderland*. Project Gutenberg Edition.

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Dantzig[illegible]S=2T[illegible]S−2T=0[illegible]S[illegible]S−2T=0[illegible]“[illegible]”[illegible]

3. Safire, W. 1990. “On Language”. *New York Times*, February 11.

[illegible]A[illegible]Z[illegible]

$A+B+C+D\geq 100$

$2E+8G-H=50$

$1.2Y-3.1X+40Z\geq 0$

[illegible]XY≥0[illegible]

[illegible]Dantzig[illegible]

[illegible]Hitchcock[illegible]Wood[illegible]Dantzig[illegible]simplex algorithm[illegible]TSP[illegible]

5.1.2 [illegible]

[illegible]A[illegible]B[illegible]C[illegible]A[illegible]B[illegible]C[illegible]100[illegible]45[illegible]200[illegible]91[illegible]A[illegible]3[illegible]4[illegible]B[illegible]3[illegible]2[illegible]C[illegible]1[illegible]8[illegible]

[illegible]$10A+5B+15C$[illegible]A[illegible]10[illegible]B[illegible]5[illegible]C[illegible]15[illegible]C[illegible]25[illegible]375[illegible]≤[illegible]

[illegible]$10A+5B+15C$[illegible]

[illegible]

$3A+3B+1C\leq 100$ [illegible]
$4A+2B+8C\leq 200$ [illegible]
$A\geq 0, B?\geq 0, C\geq 0$

[illegible]

[illegible]30[illegible]A[illegible]10[illegible]C[illegible]B[illegible]450[illegible]

5.1.3 [illegible]

1948[illegible]Dantzig[illegible][1][illegible]Harold Hotelling[illegible]“[illegible]”[illegible]Dantzig[illegible][2]

1. Cottle, R. W. 2006. Math. Program. 105, 1–8.

2. Dantzig (1991).

> [illegible]·[illegible]“[illegible]”[illegible]“[illegible]‘[illegible]’[illegible]”

[illegible]Dantzig[illegible]Dantzig[illegible]Hetelling[illegible]•[illegible][3][illegible]*Peanuts*[illegible]Linus[illegible]“[illegible]”[4]

3. Gill, P. E., et al. 2008. Discrete Optim. 5, 151–158.

4. [illegible]“Happiness Is A Warm Puppy”[illegible]——[illegible]

5.1.4 [illegible]

Linear Programming and Extensions[illegible]George Dantzig[illegible]“[illegible]

[illegible]”[1] [illegible] 600 [illegible] 60 [illegible]

1. Dantzig (1963).

[illegible] Gina Kolata [illegible]“[illegible]”[2] Hotelling [illegible]

2. Kolata, G. 1989. *New York Times*, March 12.

[illegible] Paul William [illegible] *Model Building in Mathematical Programming* [illegible][3] [illegible]…… [illegible]

3. Williams, H. P. 1999. *Model Building in Mathematical Programming*. John Wiley & Sons, Chichester, UK.

5.2 [illegible]

[illegible]

> [illegible]

——Malcolm W. Browne[illegible]1979[illegible]11[illegible]7[illegible]

> [illegible]28[illegible]

——James Gleick[illegible]1984[illegible]11[illegible]19[illegible]

[illegible]Leonid Khachiyan[illegible]Narendra Karmakar[illegible]

[illegible]Dantzig[illegible]20[illegible]80[illegible]Bob Bixby[illegible]CPLEX[illegible]IBM[illegible]John Forrest[illegible]OSL[illegible]2000[illegible]“[illegible]”[illegible]The Top Ten Algorithms of the Century[illegible][1]

1. Dongara, J., F. Sullivan. 2000. Comp. Sci. Eng. 2, 22–23.

5.2.1 [illegible]

[illegible]Vašek Chvátal[illegible]*Linear Programming*[illegible][1][illegible]

1. Chvátal, V. 1983. *Linear Programming*. W. H. Freeman and Company, New York.

[illegible]A[illegible]B[illegible]C[illegible]A[illegible]B[illegible]C[illegible]Z[illegible]N[illegible]S[illegible]

$$Z = 0 + 10A + 5B + 15C$$

$$N = 100 - 3A - 3B - C$$

$$S = 200 - 4A - 2B - 8C$$

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100/3*A*≥0□□□□□*A*□□□□□□$33\frac{1}{3}$□□□□□□□□□□□□□*S*≥0□□□*A*□□□□□□ 50□□

$$A = 33\frac{1}{3}, B = 0, C = 0$$

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$$N = 100 - 3A - 3B - C$$

□*A*□□□□□*N*□□□□□□□□□□□□3□□□□□□□□□□

$$A = 33\frac{1}{3} - \frac{1}{3}N - B - \frac{1}{3}C$$

□□□□□□□□□□□*A*□□□□□□□□□□□□□□□□*Z*□□□□*S*□□□□□□□□□□□□

$$Z = 333\frac{1}{3} - 3\frac{1}{3}N - 5B + 11\frac{2}{3}C$$

$$A = 33\frac{1}{3} - \frac{1}{3}N - B - \frac{1}{3}C$$

$$S = 66\frac{2}{3} + 1\frac{1}{3}N + 2B - 6\frac{2}{3}C$$

□□□□□□□*A*□*M*□□□□□□□□□□pivoting□□□□*A*□□□□□□□incoming variable□□*M*□□□□□□□□leaving variable□□□□□□□□□□*Z*□*S*□□□□□□□□□□□□□□□□□□*Z*□*S*□□

□□□□□□□□□□□□□□□□*N*□*B*□*C*□□□□□□□□□□□□□□

$$Z = 333\frac{1}{3},\ A = 33\frac{1}{3},\ S = 66\frac{2}{3}$$

$33\frac{1}{3}$□□□N□B□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□C□□□□□□□□□□□□□□□□□□□□□□□□□□□□□C□□□

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$$A = 33\frac{1}{3} - \frac{1}{3}C \geqslant 0$$

□□□□□*C*□□□□□□□100□□□□□

$$S = 66\frac{2}{3} - 6\frac{2}{3}C \geqslant 0$$

□□□□□*C*□□□□□□□10□□□□10<100□□□*S*□□□□□□□□□□□□□□□

□□□□□□□□□□*S*□□*C*□□□□□□□□□□□□□□□□□□□□□□□□□□□□

$$Z = 450 - N - \frac{3}{2}B - \frac{7}{4}S$$

$$A = 30 - \frac{2}{5}N - \frac{11}{10}B - \frac{1}{20}S$$

$$C = 10 - \frac{1}{5}N - \frac{3}{10}B - \frac{3}{20}S$$

[illegible]

$$N = B = S = 0,\ Z = 450,\ A = 30,\ C = 10$$

[illegible] Z=450−N−32B−74S [illegible] 450 [illegible] N [illegible] B [illegible] S [illegible] 450 [illegible]

[illegible] Chvátal [illegible]

[illegible] Bob Vanderbei [illegible] Simplex Pivot Tool [illegible][3] [illegible]

3. http://campuscgi.princeton.edu/ [illegible] rvdb/JAVA/pivot/simple.html [illegible] Vanderbei, R. J. 2001. *Linear Programming: Foundations and Extensions*. Kluwer, Boston, MA.

5.2.2 [illegible]

Dantzig [illegible]

2009 [illegible] IEEE FOCS [illegible] 50 [illegible] Richard Karp [illegible]“[illegible]”[illegible] Karp [illegible]

[illegible]

[illegible]

[illegible]Dantzig[illegible][1]

1. Albers and Reid (1986).

> [illegible]corner point[illegible]

[illegible]Dantzig[illegible]

[illegible]

5.2.3 [illegible]

Dantzig[illegible]1948[illegible]“[illegible]·[illegible]·[illegible]”[1][illegible]Dantzig[illegible]

1. Dantzig, G. B. 1949. Econometrica 17, 74–75.

[illegible]1947[illegible]120[illegible][2][illegible]9[illegible]77[illegible]

2. Dantzig, G. B. 1982. Oper. Res. Let. 1, 43–48. [illegible]——[illegible]

[illegible]1984[illegible]Karmarkar[illegible]interior-point method[illegible]1987[illegible]2002[illegible]Bob Bixby[illegible]“[illegible]

[illegible]10[illegible]30[illegible]”[3][illegible]
[illegible]
[illegible]Dantzig[illegible]

3. Bixby, R. E. 2002. Operations Research 50, 3–15.

5.2.4 [illegible]

[illegible]simplex algorithm[illegible]simple[illegible]n+1[illegible]n[illegible]Dantzig[illegible]Theodore Motzkin[illegible]“‘[illegible]’[illegible]T. Motzkin[illegible]”[1][illegible]“Dantzig[illegible]”[illegible]

1. Dantzig (1991).

5.3 [illegible]

[illegible]Bob Bixby[illegible]Dantzig[illegible]duality[illegible]

[illegible]

$$Z = 450 - N - \frac{3}{2}B - \frac{7}{4}S$$

[illegible]Z[illegible]Z[illegible]N[illegible]S[illegible]Z[illegible]450[illegible]

[illegible]N[illegible]S[illegible]Z[illegible]

$$1 \times \left(3A + 3B + 1C \leqslant 100\right)$$

[illegible]

$$\frac{7}{4} \times \left(4A + 2B + 8C \leqslant 200\right)$$

[illegible]

$$10A + 6\frac{1}{2}B + 15C \leqslant 450$$

[illegible] $10A+5B+15C$[illegible]450[illegible]B[illegible]profit margin[illegible]6.5[illegible]

[illegible]N[illegible]S[illegible]y_N[illegible]y_S[illegible]A[illegible]B[illegible]C[illegible]

[illegible]y_N[illegible]y_S[illegible]

[illegible]$100\,y_N + 200\,y_S$[illegible]

□□□□

$$3y_N + 4y_S \geqslant 10$$

$$3y_N + 2y_S \geqslant 5$$

$$1y_N + 8y_S \geqslant 15$$

$$y_N \geqslant 0,\ y_S \geqslant 0$$

□□□□□□□□□□□□A□B□C□□□□□□□□□□□□□y_N□y_S□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□y_N□y_S□□□□□□□□□□□□□□□□□□□□□□$100\ y_N + 200\ y_S$□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

□□□□□□□□□□□□dual problem□□□Dantzig□□□Tobias□□□□□□□□□□□□primal problem□□□ $10A + 5B + 15C \leq 100y_N + 200y_S$□

□□□□□□□□□□□□

$$A = 30,\ B = 0,\ C = 10,\ y_N = 1,\ y_S = \frac{7}{4}$$

□□□□□□□□□450□□□□□450□□□

□□strong duality theorem□□□□□□·□·□□□□□□□□[2]

2. □□□

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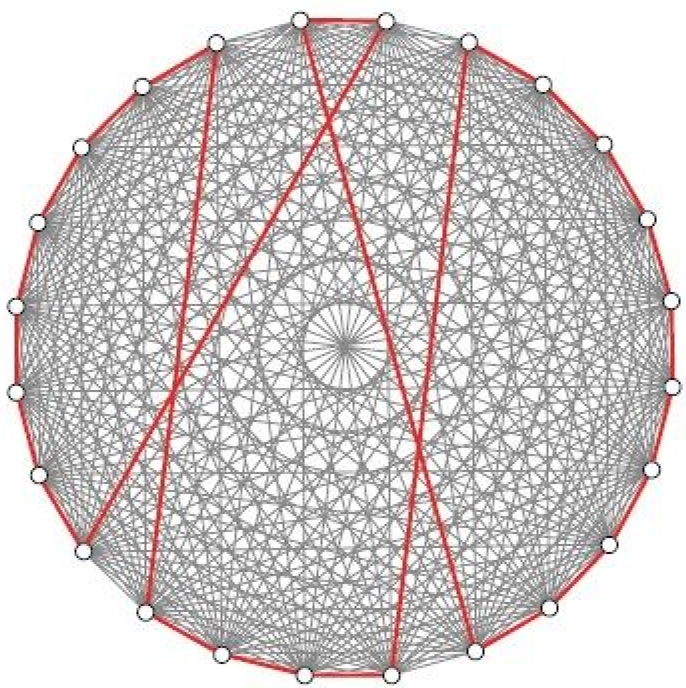
5.4 TSP□□□□□□□□□□□□

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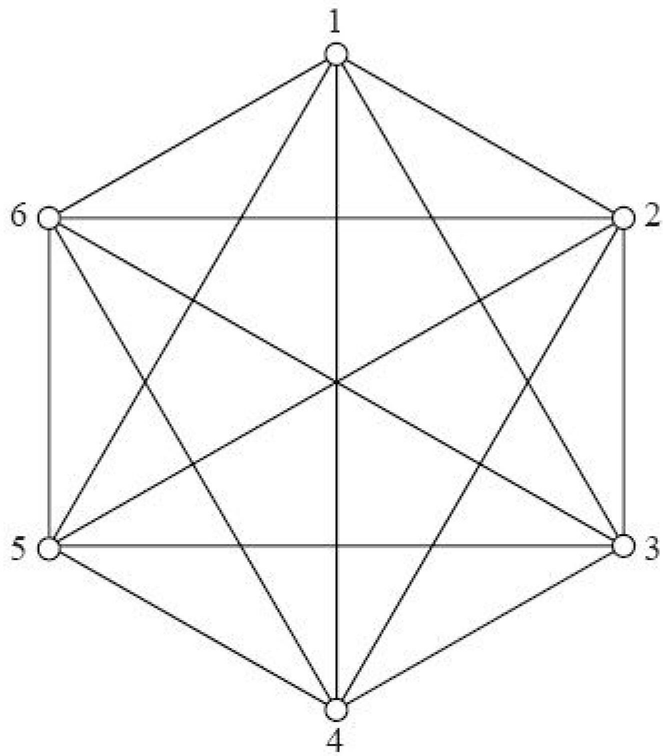
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□□Dantzig□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□

5.4.1 □□□□□

[illegible]

Julia Robinson[illegible] x_{ij} [illegible] 2 [illegible] degree constraint [illegible]

[illegible] $c_{12}x_{12} + c_{13}x_{13} + \ldots + c_{56}x_{56}$ [illegible]

[illegible]

$$x_{12} + x_{13} + x_{14} + x_{15} + x_{16} = 2$$

$$x_{12} + x_{23} + x_{24} + x_{25} + x_{26} = 2$$

$$x_{13} + x_{23} + x_{34} + x_{35} + x_{36} = 2$$

$$x_{14} + x_{24} + x_{34} + x_{45} + x_{46} = 2$$

$$x_{15} + x_{25} + x_{35} + x_{45} + x_{56} = 2$$

$$x_{16} + x_{26} + x_{36} + x_{46} + x_{56} = 2$$

(i,j)[illegible] $x_{ij} \geq 0$

[illegible] TSP [illegible] degree LP relaxation [illegible]

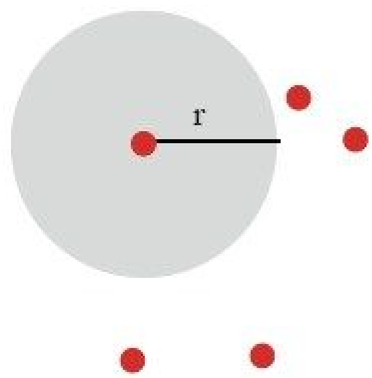
[illegible] TSP [illegible] TSP [illegible] X [illegible] X [illegible] 450 [illegible]

5.4.2 [illegible]

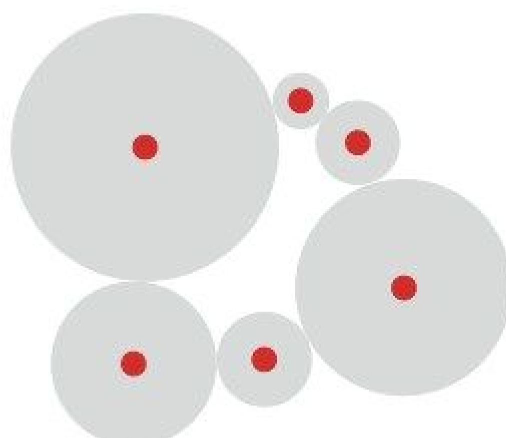
[illegible] Michael Jünger [illegible] William Pulleyblank [illegible] TSP [illegible][1] [illegible] TSP [illegible]

1. Jünger, M., W. R. Pulleyblank. 1993. In: S. D. Chatterji et al., eds. *Jahrbuch Überblicke Mathematik*. Vieweg, Brunschweig/Wiesbaden, Germany. 1–24.

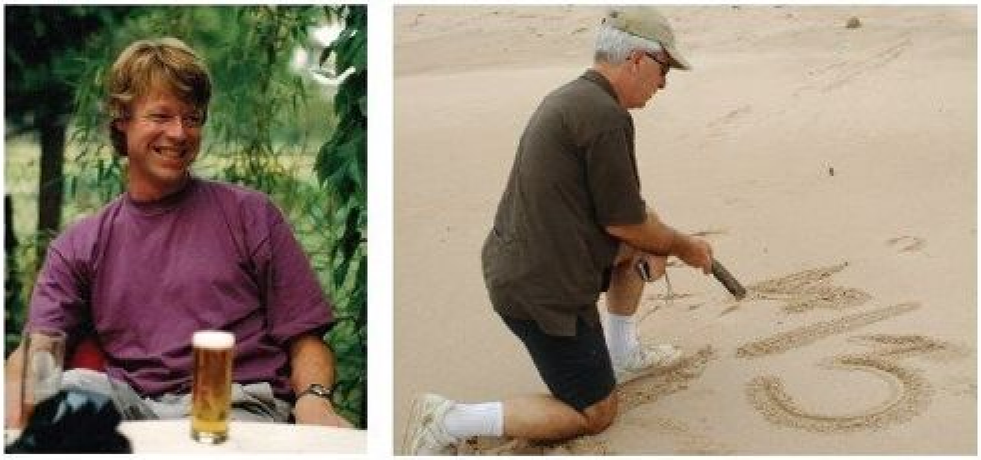
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□□□□□□□□□□□□□□□□□Jünger□Pulleyblank□□□□□□□□
□control zone□□



□5-4 1□□□



□5-5 6□□□



[illegible]5-6 Michael Jünger[illegible]Regine Strobl[illegible]William Pulleyblank[illegible]Nick Harvey[illegible]

[illegible] i [illegible] j [illegible] r_i [illegible] r_j [illegible] r_i [illegible] r_j [illegible]

$$r_i + r_j \leqslant c_{ij}.$$

[illegible]

[illegible] $2r_1 + 2r_2 + 2r_3 + 2\,r_4 + 2r_5 + 2r_6$ [illegible]

[illegible]

$$r_1 + r_2 \leqslant c_{12},\ r_1 + r_3 \leqslant c_{13},\ r_1 + r_4 \leqslant c_{14}$$

$$r_1 + r_5 \leqslant c_{15},\ r_1 + r_6 \leqslant c_{16},\ r_2 + r_3 \leqslant c_{23}$$

$$r_2 + r_4 \leqslant c_{24},\ r_2 + r_5 \leqslant c_{25},\ r_2 + r_6 \leqslant c_{26}$$

$$r_3 + r_4 \leqslant c_{34},\ r_3 + r_5 \leqslant c_{35},\ r_3 + r_6 \leqslant c_{36}$$

$$r_4 + r_5 \leqslant c_{45},\ r_4 + r_6 \leqslant c_{46},\ r_5 + r_6 \leqslant c_{56}$$

[illegible] TSP [illegible]

[illegible] i [illegible] y_i [illegible] i [illegible] y_i [illegible] x_{ij} [illegible]

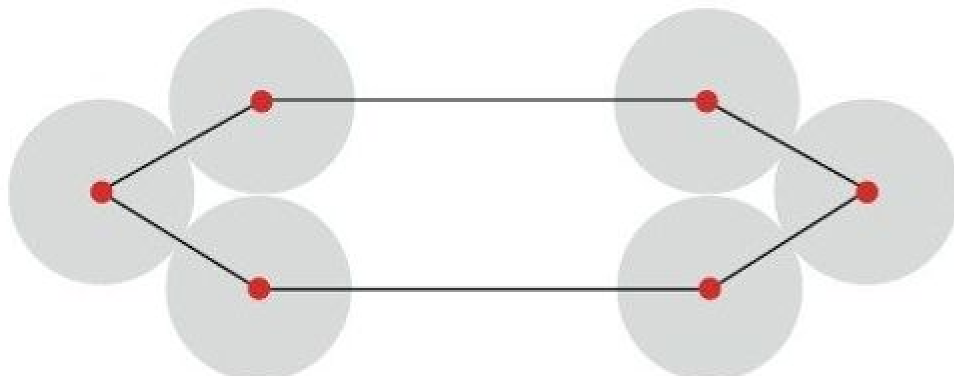
c_{ij} [illegible] c_{ij} [illegible] i [illegible] j [illegible] $y_i + y_j \leq c_{ij}$ [illegible]

[illegible] r_i [illegible] y_i [illegible]

[illegible]

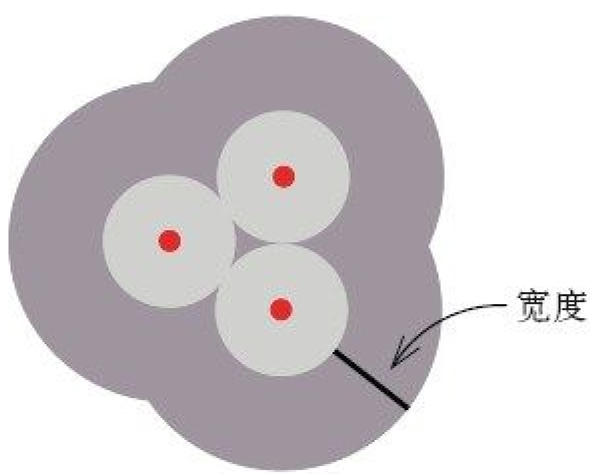
5.5 □□□□□

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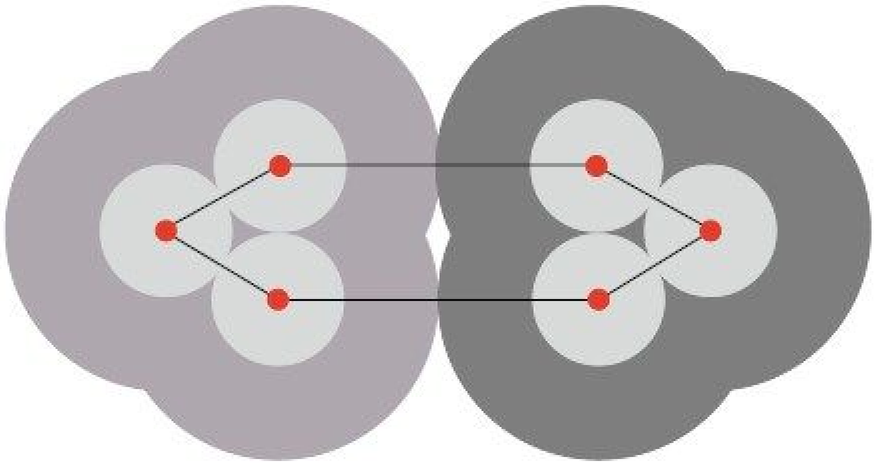
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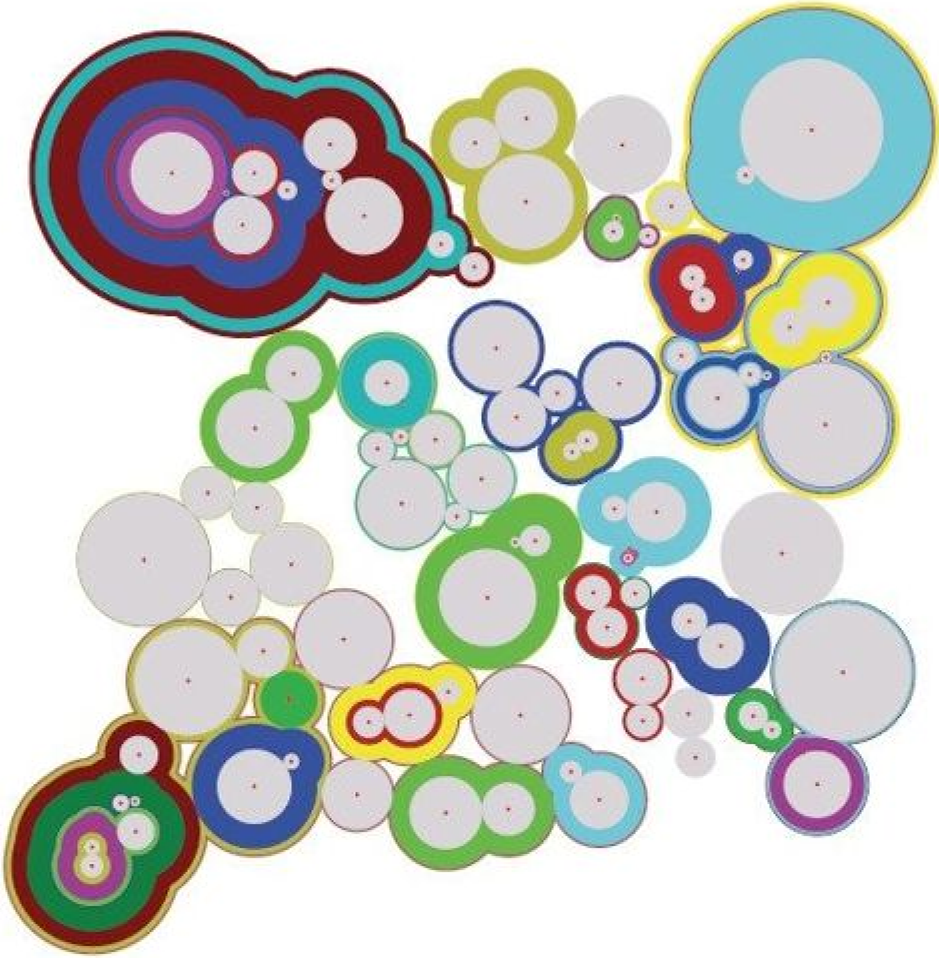


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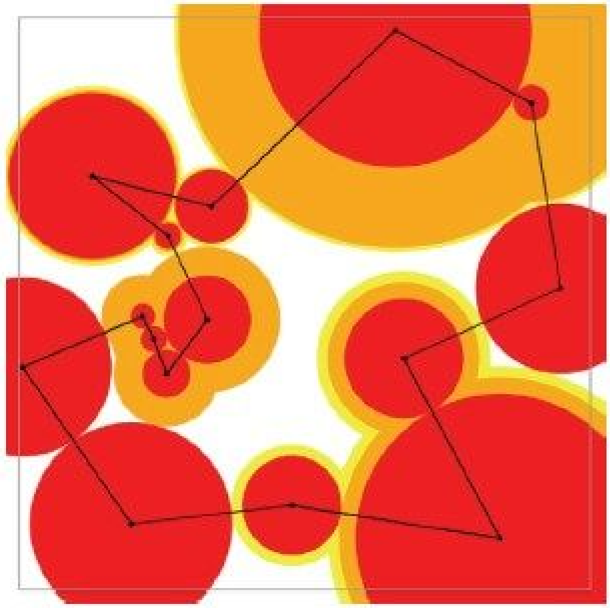


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□5-10 □□□□□□□□□□□

□□100□□□Geodual□□□□□□□□□□□□□Mike Jünger□□□□□□□[1]□□□□□20□□□□□□□□TSP□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□5-11□



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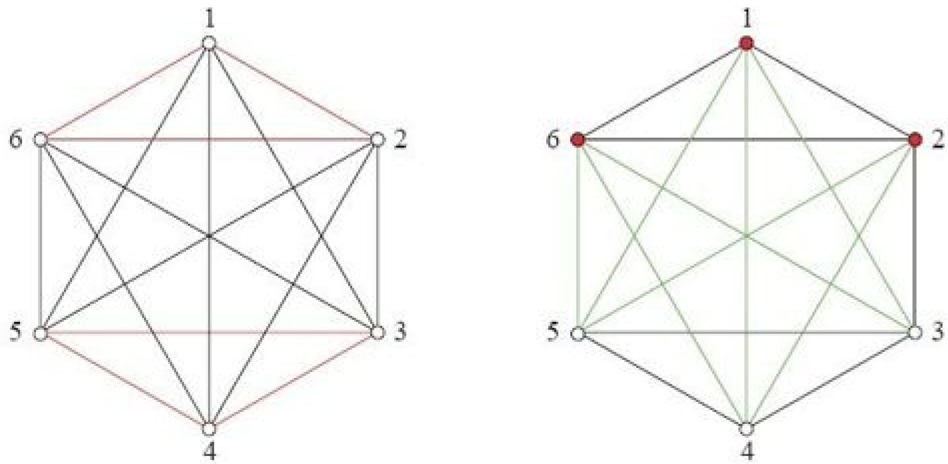
1. □□http://www.informatik.uni-koeln.de/ls_juenger/research/geodual/□

5.5.1 □□□□□□

□□□TSP□□□5-7□6□□□TSP□□□

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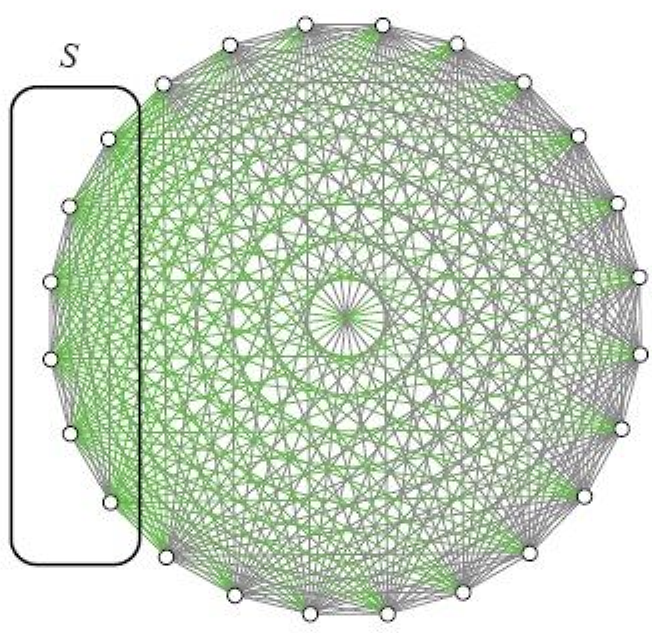
$$x_{13}+x_{14}+x_{15}+x_{23}+x_{24}+x_{25}+x_{63}+x_{64}+x_{65}\geqslant 2$$



[illegible]5-12 [illegible]

[illegible]5-12[illegible]subtour-elimination constraint[illegible]subtour inequality[illegible]

[illegible]*S*[illegible]*S*[illegible]*S*[illegible]2[illegible]5-12[illegible]*S*={1, 2, 6}[illegible]5-13[illegible]*S*[illegible]



[illegible]5-13 [illegible]

[illegible]subtour LP relaxation[illegible]TSP[illegible]

[illegible]1%[illegible]42[illegible]697[illegible]699[illegible]0.3%[illegible]

5.5.2 “4/3[illegible]”

[illegible]3/2[illegible]Christofides[illegible]

[illegible]4/3[illegible]4/3[illegible]“4/3[illegible]”[illegible]4/3rds Conjecture[illegible]Sylvia Boyd[illegible][1]

1. Benoit, G., S. Boyd. 2008. Math. Oper. Res. 33, 921–931.

[illegible]3/2[illegible]4/3[illegible][2][illegible]TSP[illegible]

2. [illegible]Michel Goemans[illegible]LP[illegible]





[illegible]5-14 Sylvia Royd[illegible]Richard Haynes[illegible]Bellairs Workshop 2007[illegible]Nick Harvey[illegible]“4/3[illegible]”[illegible]Bill Pulleyblank[illegible]

5.5.3 [illegible]

[illegible]0[illegible]1[illegible]2[illegible]x_{ij}[illegible]2[illegible]i[illegible]j[illegible]S={i, j}[illegible]x_{ij}≤1[illegible]0[illegible]1/2[illegible]1[illegible]

5.6 [illegible]

[illegible]TSP[illegible]

5.6.1 [illegible]

[illegible]George Dantzig[illegible]

[illegible]

[illegible]x+2y[illegible]

[illegible]

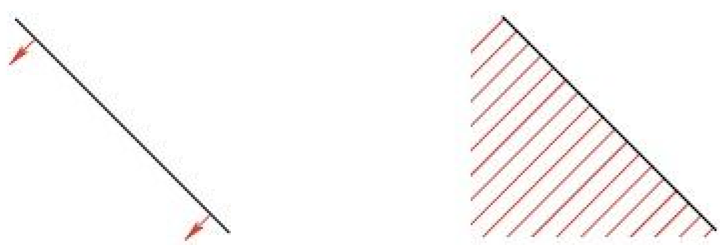
$$x + y \leqslant 13$$

$$x \leqslant 8,\ y \leqslant 8$$

$$x \geqslant 0,\ y \geqslant 0$$

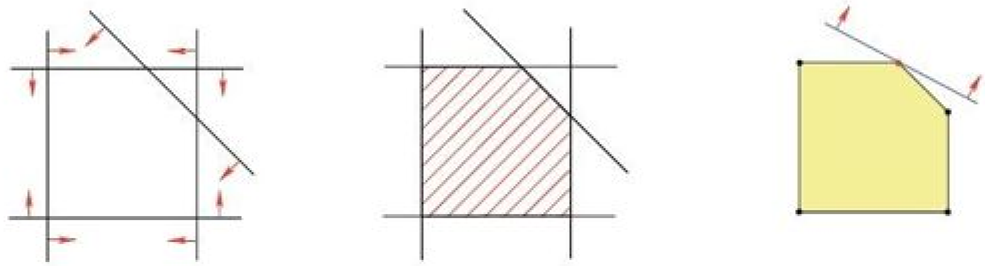
[illegible](x, y)[illegible]x[illegible]y[illegible]

[illegible]feasible region[illegible]x+y≤13[illegible]x+y=13[illegible](x, y)[illegible]halfspace[illegible]5-15[illegible]



[illegible]5-15 [illegible]

[illegible]5-16[illegible](5, 8)[illegible]



[illegible]5-16 [illegible]

[illegible](8, 5)[illegible](8, 0)[illegible](0, 0)[illegible](0, 8)[illegible]

[illegible]

[illegible]George Dantzig[illegible]“[illegible]”[illegible]*d*[illegible]*d*[illegible]

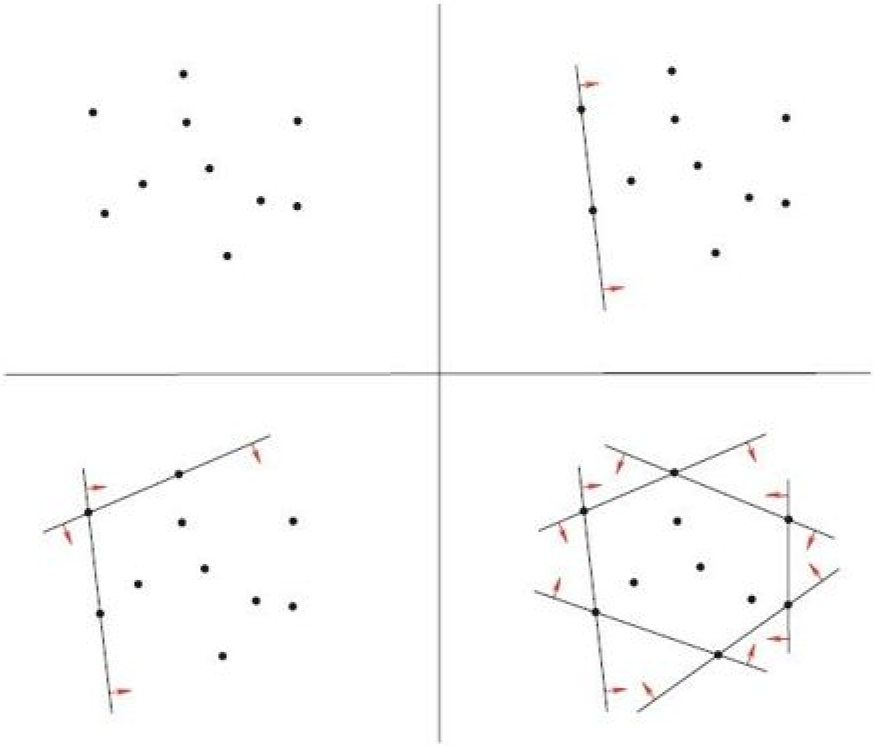
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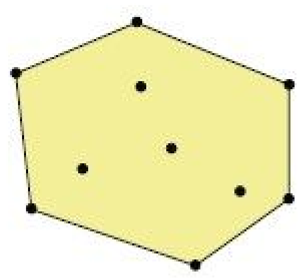
15[illegible](x, y)[illegible]5-17[illegible]

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□·□□□□□□Hermann Minkowski□



□5-18 □□

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[illegible]convex polytope[illegible]Günter Ziegler[illegible]*Lectures on Polytopes*[illegible][2]

1. [illegible]——[illegible]

2. Ziegler, G. 1995. *Lectures on Polytopes*. Springer, Berlin, Germany.

5.6.3 TSP[illegible]

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1. Christof, T., G. Reinelt. 2001. Int. J. Comput. Geom. Appl. 11, 423–437.

> [illegible]George[illegible]Selmer Johnson[illegible]Ray Fulkerson[illegible]Alan Hoffman[illegible]face[illegible]

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5.7 [illegible]

[illegible]33+1/3[illegible]“[illegible]”[illegible]“[illegible]”[illegible]“[illegible]”[illegible]“[illegible]”[illegible]0[illegible]1[illegible]

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Dantzig[illegible][1][illegible]1963[illegible][2][illegible]

1. Dantzig, G. B. 1960. Econometrica 28, 30–44.

2. Dantzig (1963).

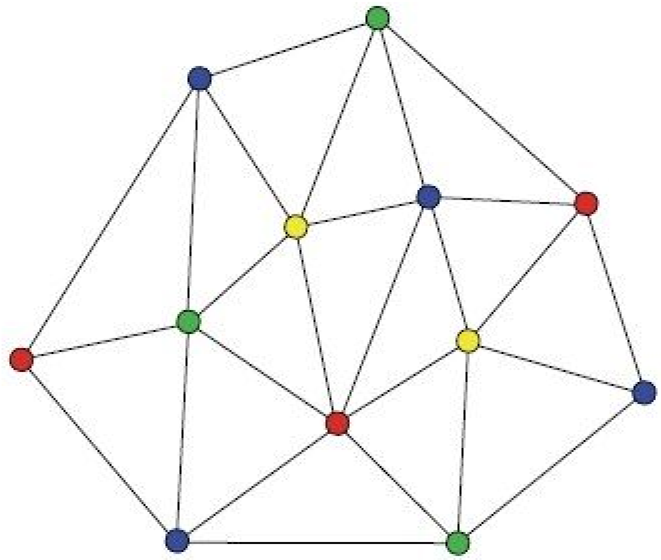
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$$x_{i,red} + x_{i,green} + x_{i,blue} = 1$$



□5-19 □4□□□□□

□□□□□□i, j□□□□□□□□□i□j□□□□□□□□□□□□□□□□□□

$$x_{i,red} + x_{j,red} \leqslant 1$$

$$x_{i,green} + x_{j,green} \leqslant 1$$

$$x_{i,blue} + x_{j,blue} \leqslant 1$$

□□1/3□□□

5.7.1 TSP□□□□□□

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□□□Dantzig□□□□□□□□□□TSP□□□□□□□□□n^3□□□□□□□□□□□□□
$n+n^2$□□□Albert Tucker□□□□□TSP□□□

[illegible] TSP [illegible]

5.7.2 [illegible]

[illegible] TSP [illegible] TSP [illegible] TSP [illegible]

[illegible] 20 [illegible] TSP [illegible] IP [illegible]

5.8 [illegible]

[illegible]operations research[illegible]OR[illegible]O.R.[illegible]

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[illegible]“[illegible]The Science of Better[illegible]”[illegible]Institute for Operations Research and Management Science[illegible]INFORMS[illegible]“[illegible]”[illegible]“[illegible]”[illegible]

[illegible]Michael Trick[illegible]INFORMS[illegible][1][illegible]TSP[illegible][2]

1. [illegible]http://mat.tepper.cmu.edu/blog/[illegible]

2. Laura McLay[illegible]“[illegible]”[illegible]http://punkrockor.wordpress.com/[illegible]



图5-20　Michael Trick（2010）

[illegible]6[illegible]

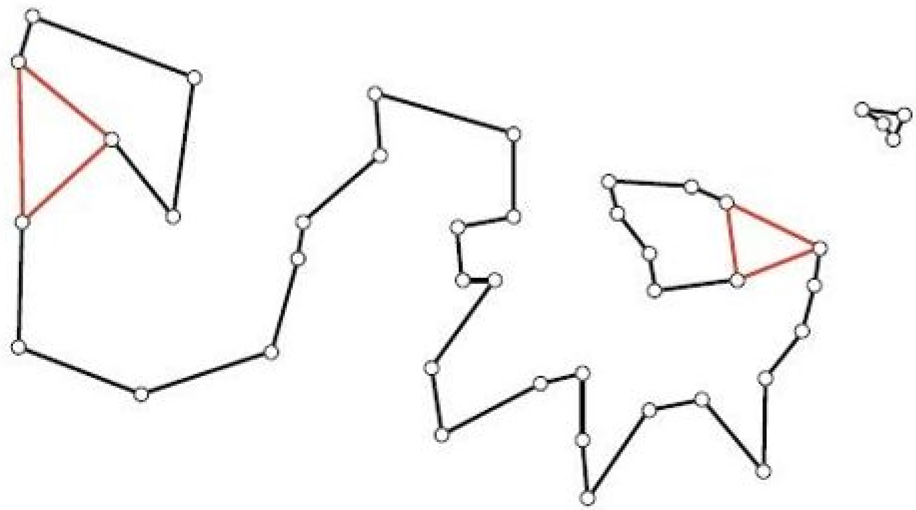
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>
> ——Alan Hoffman[illegible]Philip Wolfe[illegible]1985[illegible][1]

1. Hoffman[illegible]Wolfe (1985).

[illegible]Dantzig[illegible]Fulkerson[illegible]Johnson[illegible]“[illegible]”[illegible]TSP[illegible]

6.1 □□□□

Dantzig□□□
□6-1□□□□□□□□□□□□□1/2□□□□□□□□1□□□□□□□□□□0□

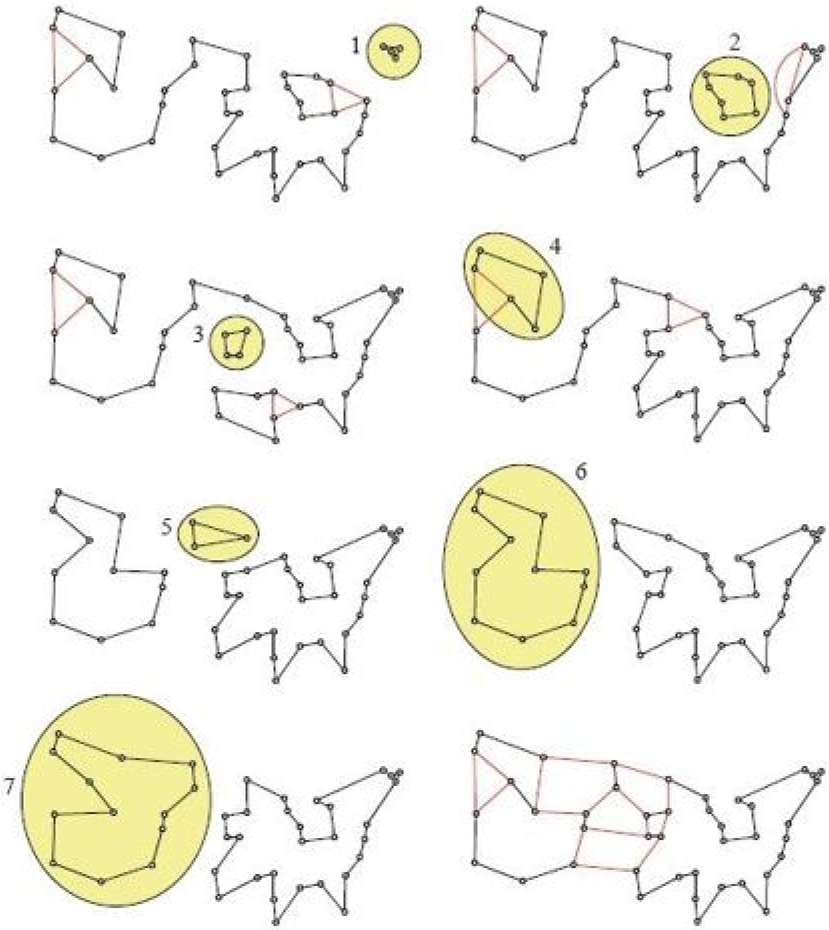


□**6-1**　□□□□□□□□□□□□□□□□□□□□□□□

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□□□□□□□□□□□6-2□□Dantzig□□□□□□□□□□□□□□Edwin Paxson□□□□□“□□□□□□”[1]□□□□□□□□□□□□□□□



[illegible]6-2 [illegible]

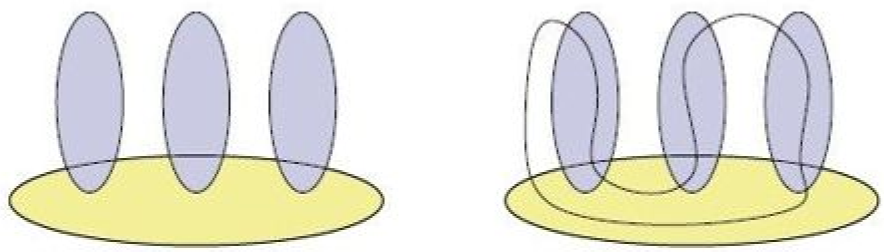
1. Dantzig, G., R. Fulkerson, S. Johnson. 1954. Technical Report P-510, RAND Corporation, Santa Monica, California. [illegible]·[illegible]·[illegible]“[illegible]”[illegible]“[illegible]”[illegible]——[illegible]

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[illegible]697[illegible]699[illegible]2[illegible]697[illegible]1[illegible]

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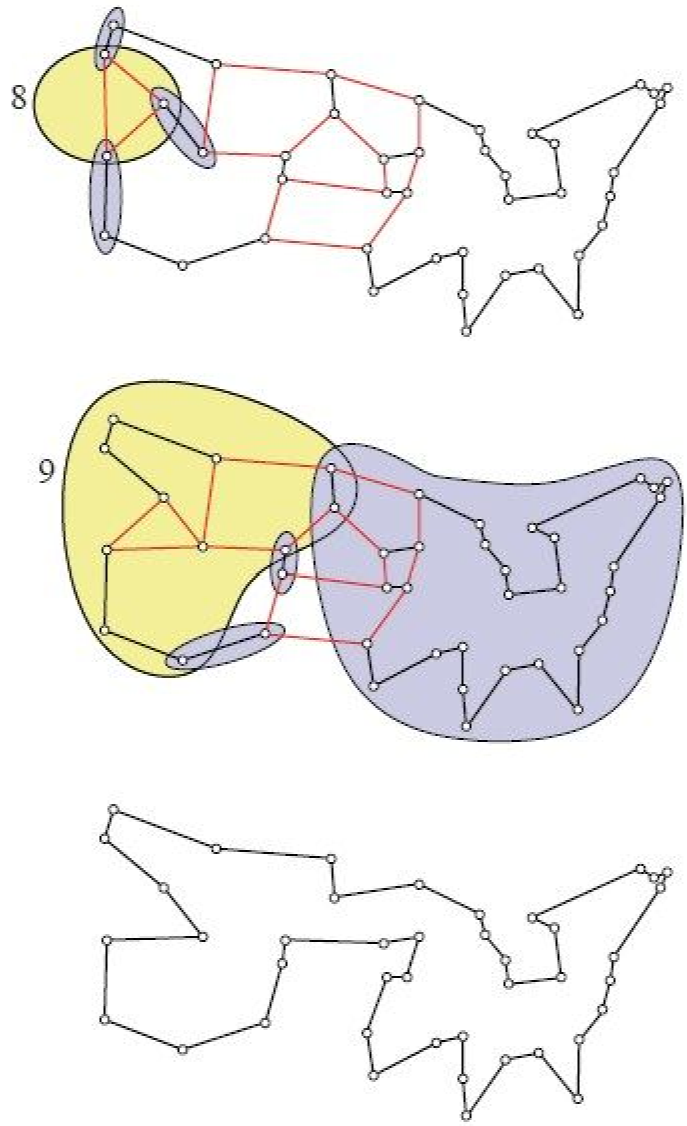
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[illegible]6-3 [illegible]10[illegible]

2. [illegible]2[illegible]3[illegible]3[illegible]4[illegible]3[illegible]2[illegible]1[illegible]4[illegible]10[illegible]

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[illegible]6-4 [illegible]

3. [illegible]

[illegible]9[illegible]9[illegible]

[illegible]9[illegible]cutting plane[illegible]“[illegible]”[illegible]Paxson[illegible]“[illegible]”[illegible]

[illegible]Dantzig[illegible][4]

4. Dantzig et al. (1954).

> [illegible]

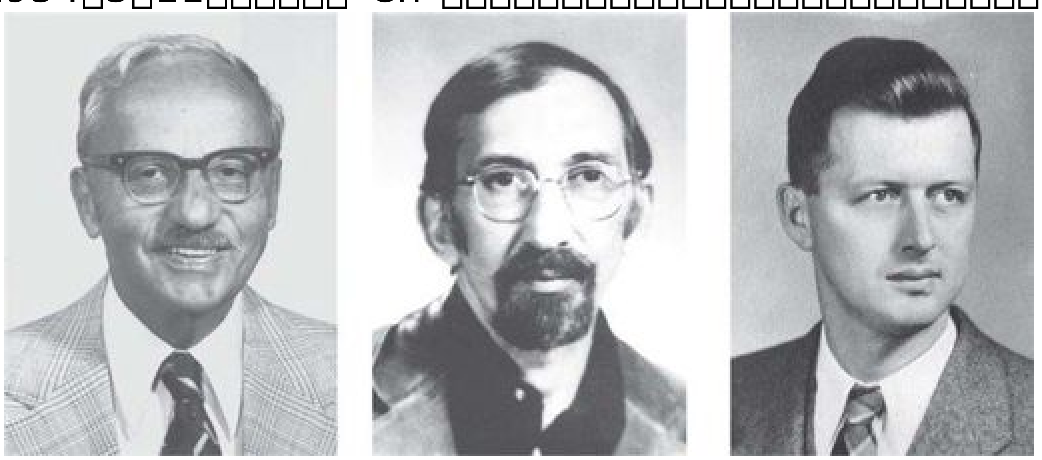
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6.2 TSP□□□□□

Dantzig□□□Irving Glicksberg□□□□□□□□“□□□□□□□□□I. Glicksberg□□□□□□□□□□□□□□□□”[1]

1. Dantzig et al. (1954).

Fulkerson□□□□□□□□□□□□□□□□□□□□□□□□□□□□Glicksberg□□□□□□□□□□□□□□TSP□□□□Isidor Heller□□□□□□□□□□□□□□1954□3□11□□□□□□“Cn”□□□□□□□□□□□□□□□□□□□□□□□□□□□□n□



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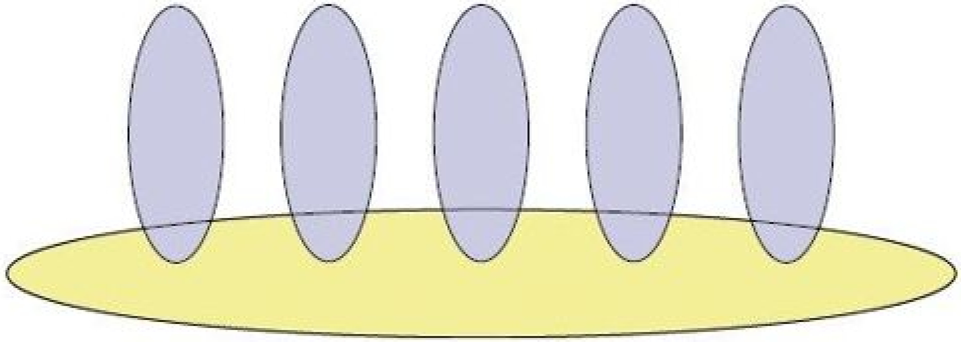
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□6-6 Vašek Chvátal□□□□Adrian Bondy□□□□□□□□□□

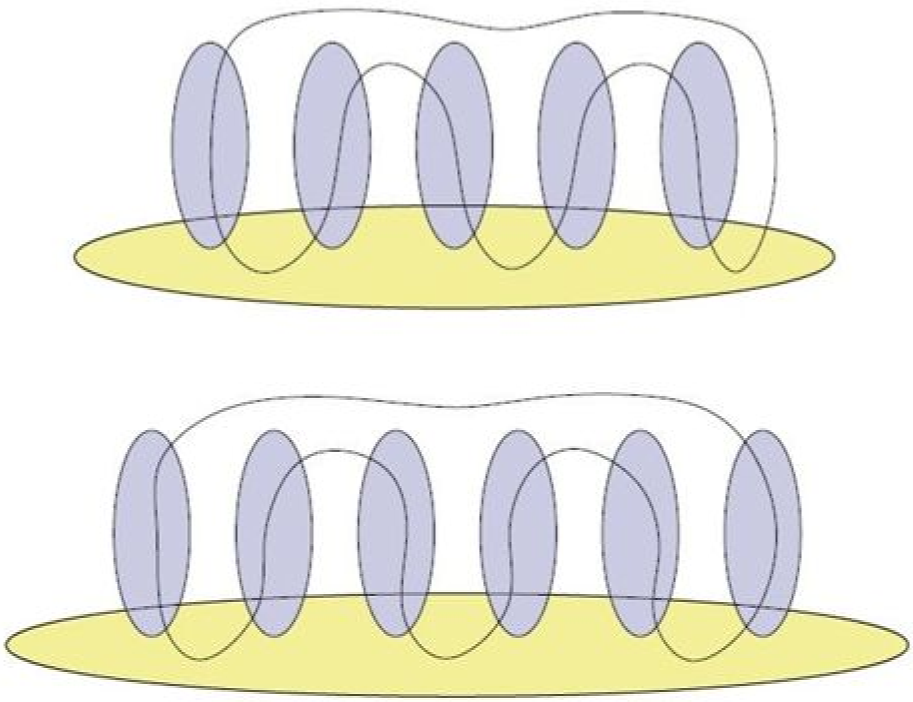
1. Chvátal, V. 1973. Math. Program. 5, 29–40.
2. Grötschel, M., M. W. Padberg. 1979. Math. Program. 16, 265–280.

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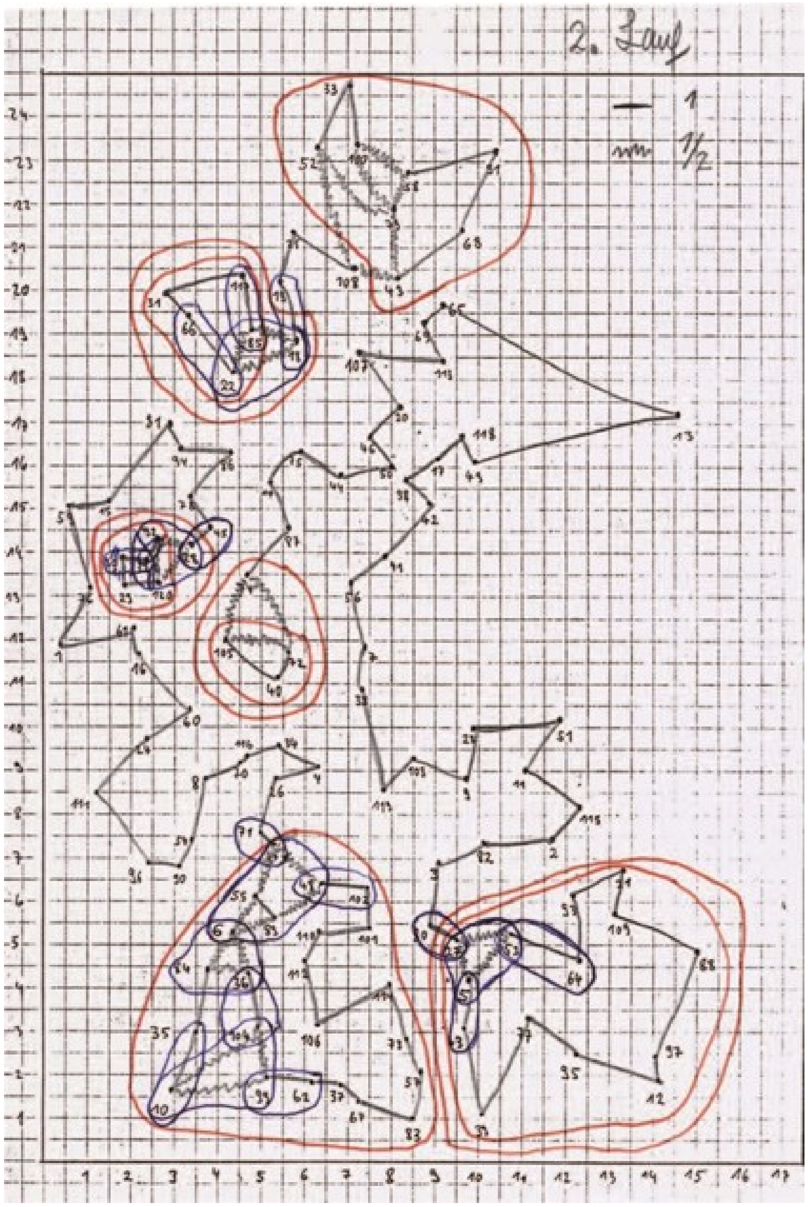
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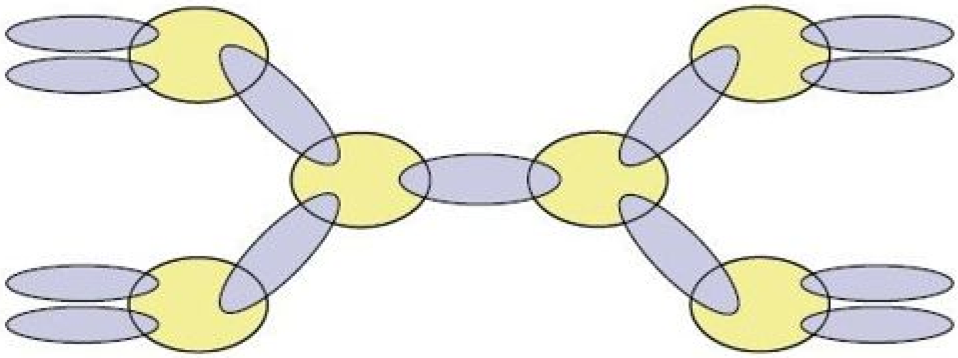


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6.2.2 TSP[illegible]

Grötschel[illegible]TSP[illegible]William Pulleyblank[illegible][1][illegible]clique tree[illegible]6-10[illegible]

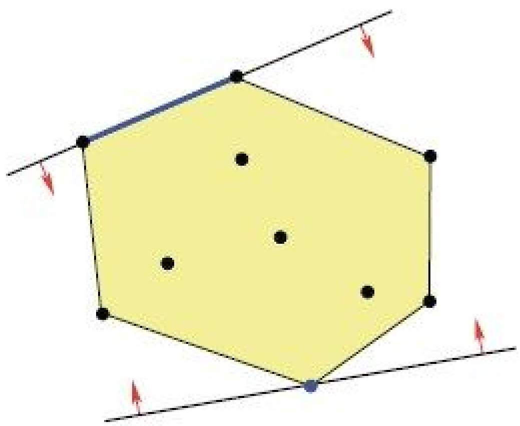
1. Grötschel, M., W. R. Pulleyblank. 1986. Math. Oper. Res. 11, 537–569.



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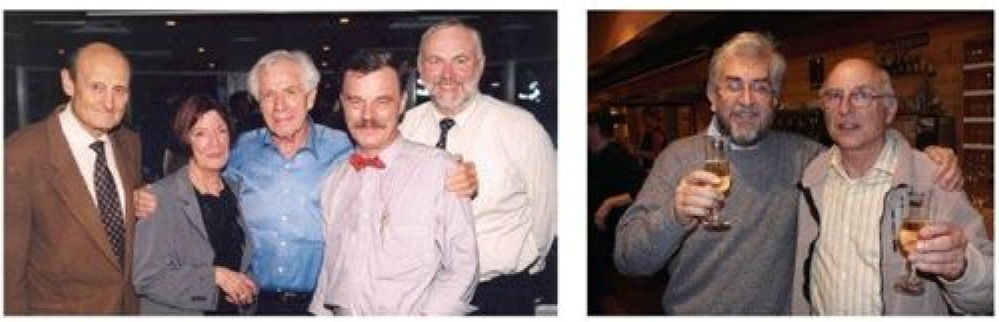
3. Grötschel, M., M. W. Padberg. 1979. Math. Program. 16, 265-280.

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4. Naddef, D. 2002. In: G. Gutin, A. Punnen, eds. *The Traveling Salesman Problem and Its Variations*. Kluwer, Boston, Massachusetts. 29–116.



□6-12 □□□Egon Balas□Suzy Mouchet-Padberg□Harold Kuhn□Manfred Padberg□Martin Grötschel□2001□□□□□□□□□□□□Martin Grötschel□□□□□□□Giovanni Rinaldi□Denis Naddef□2008□□□□□Aussois□□□□Uwe Zimmermann□□□

6.3 TSP[illegible]

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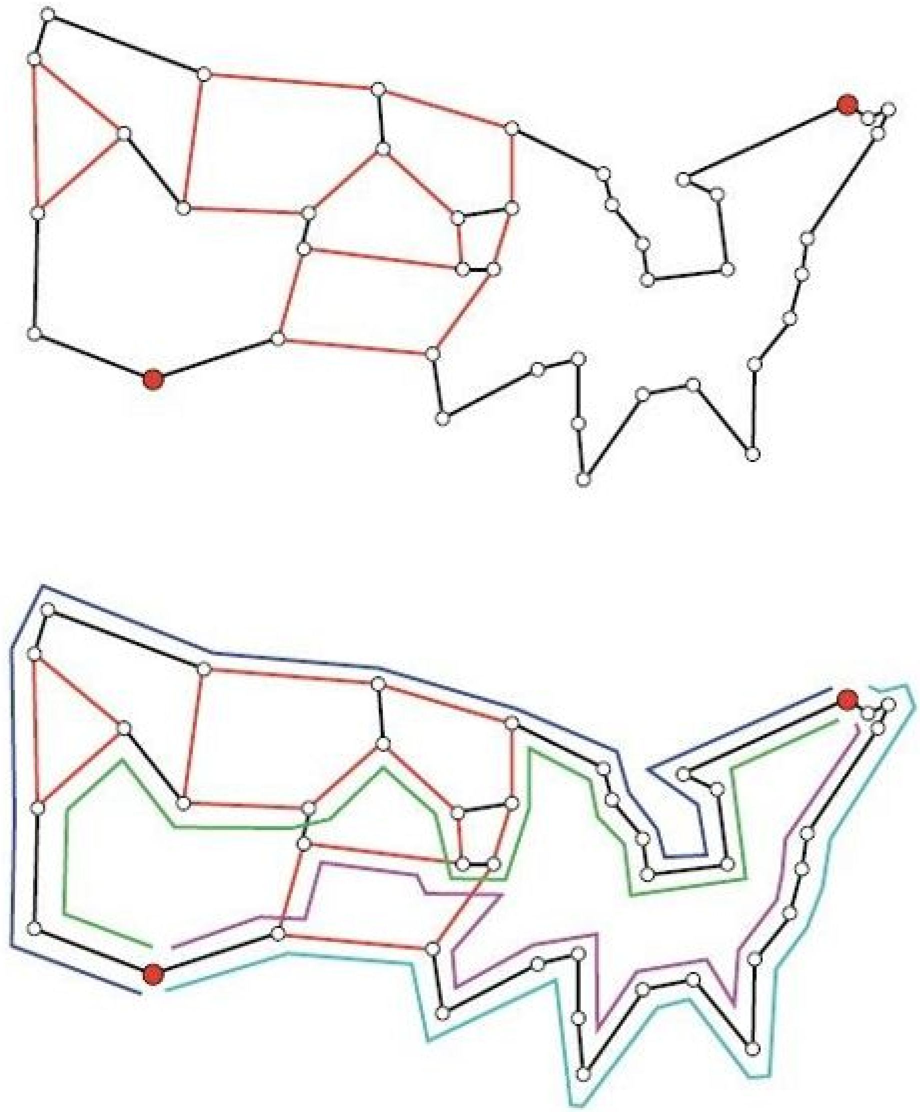
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6.3.1 [illegible]

[illegible]“[illegible]”[illegible][1]

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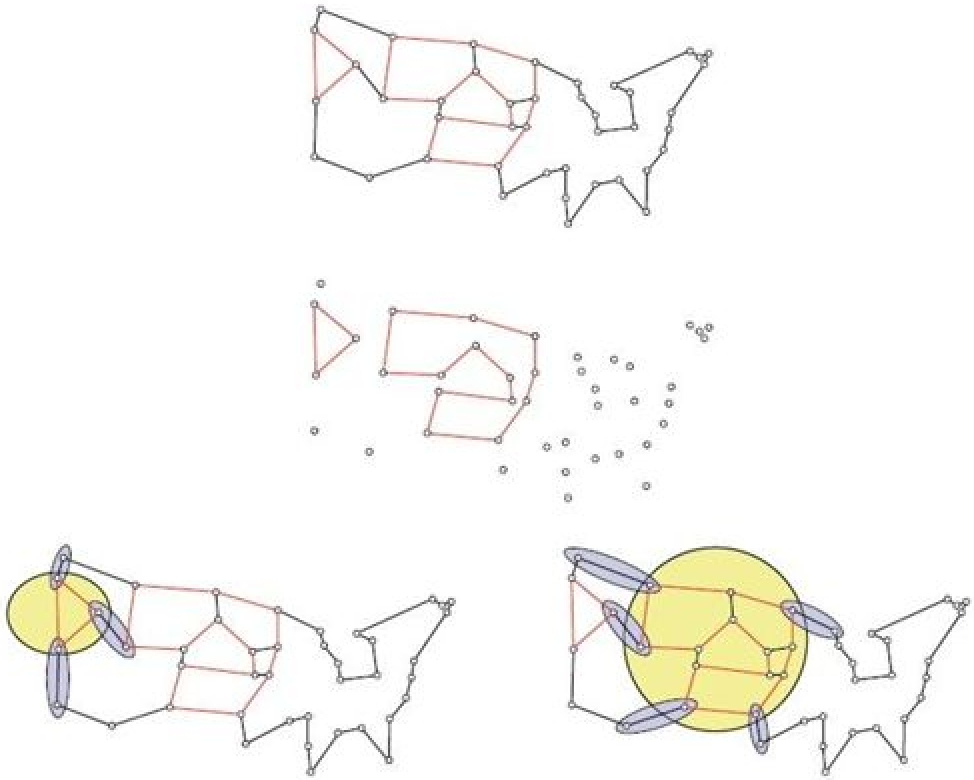
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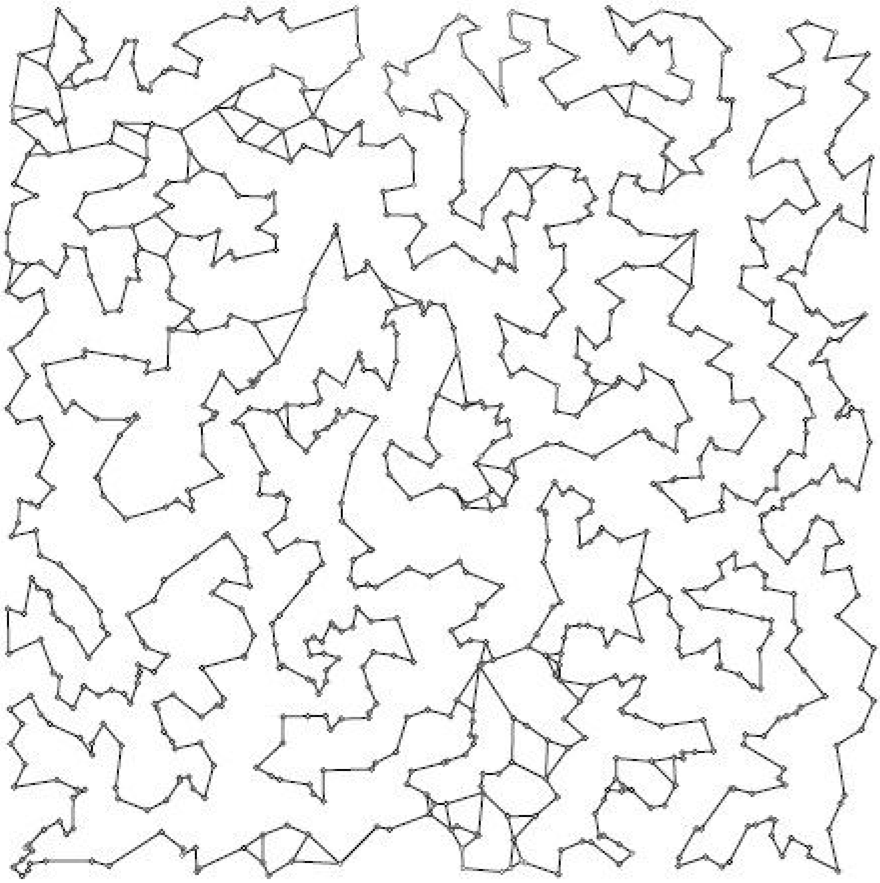
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[illegible]Jack Edmonds[illegible][1][illegible]

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2. Edmonds (1991).

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Ralph Gomory[illegible]IBM[illegible]Alfred P. Sloan Foundation[illegible]20[illegible]50[illegible]Gomory[illegible]Diophantine analysis[illegible][1]

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> ——John Little□□□1963□[1]

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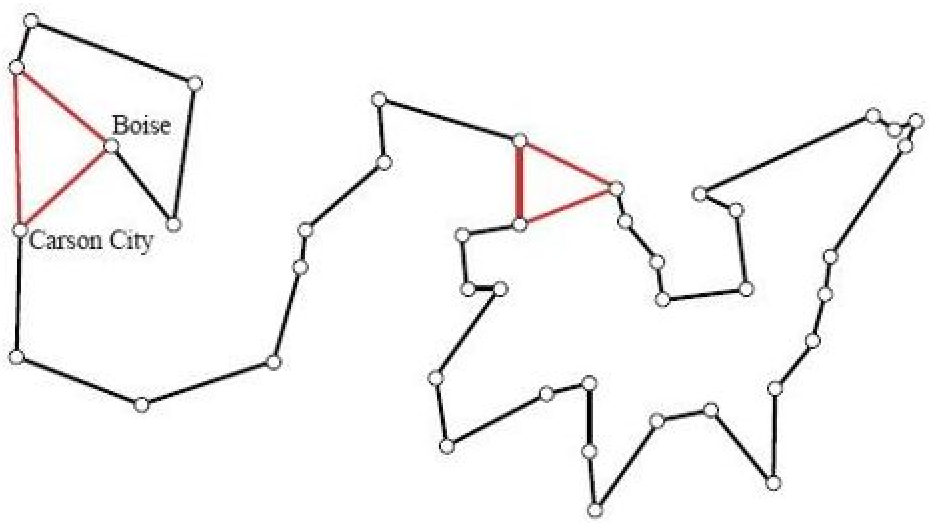
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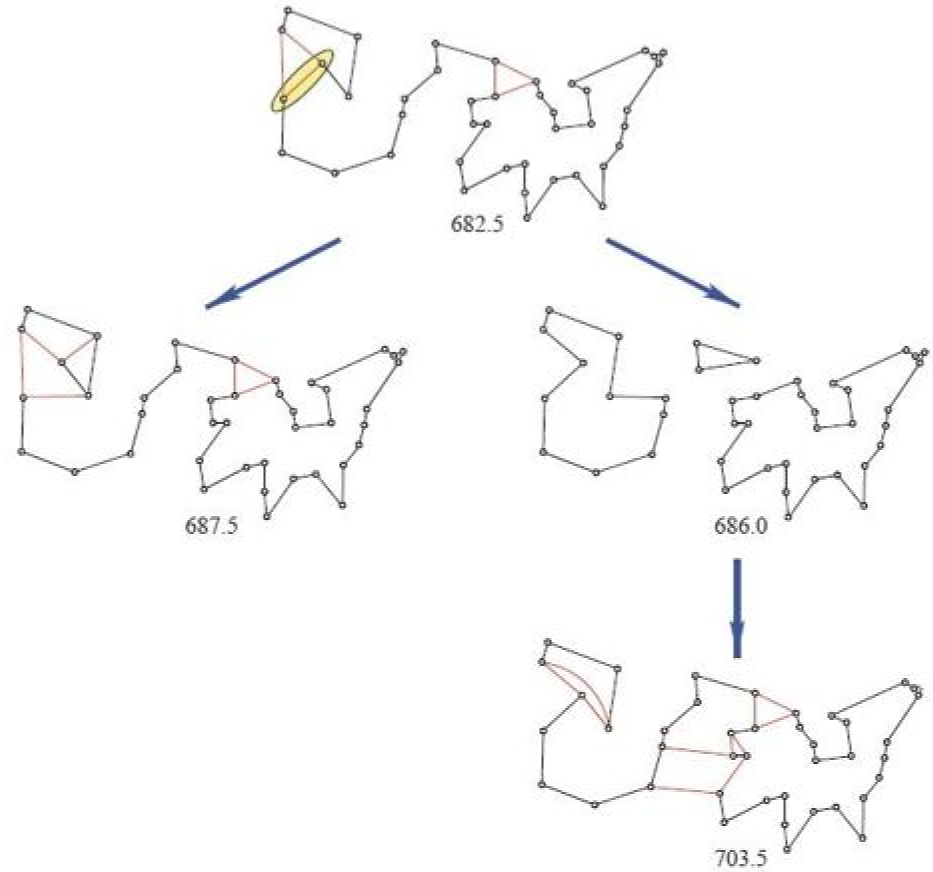
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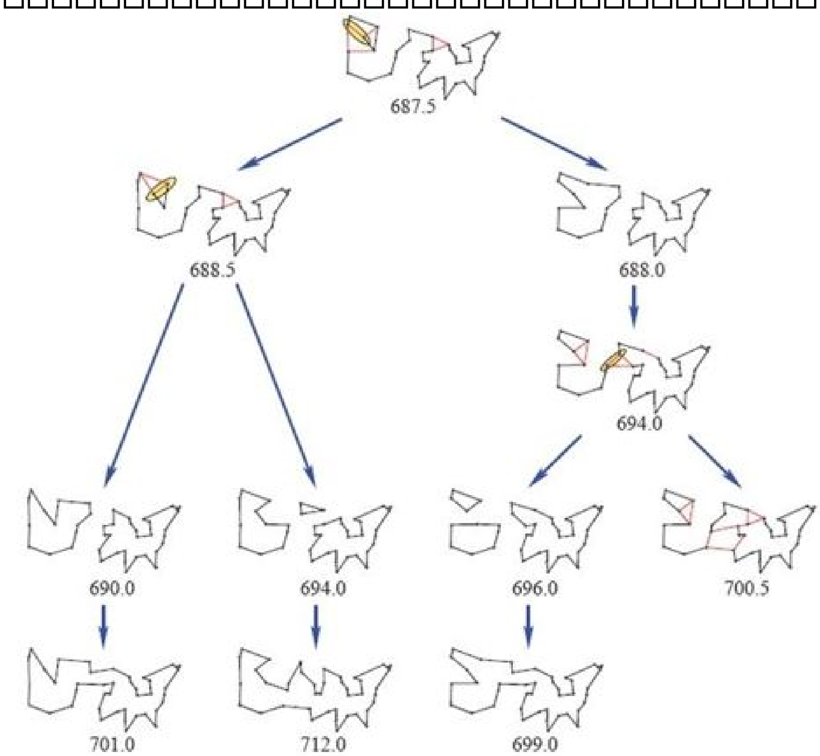
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> ——George Nemhauser[illegible]Martin Grötschel[illegible]2008[illegible][1]

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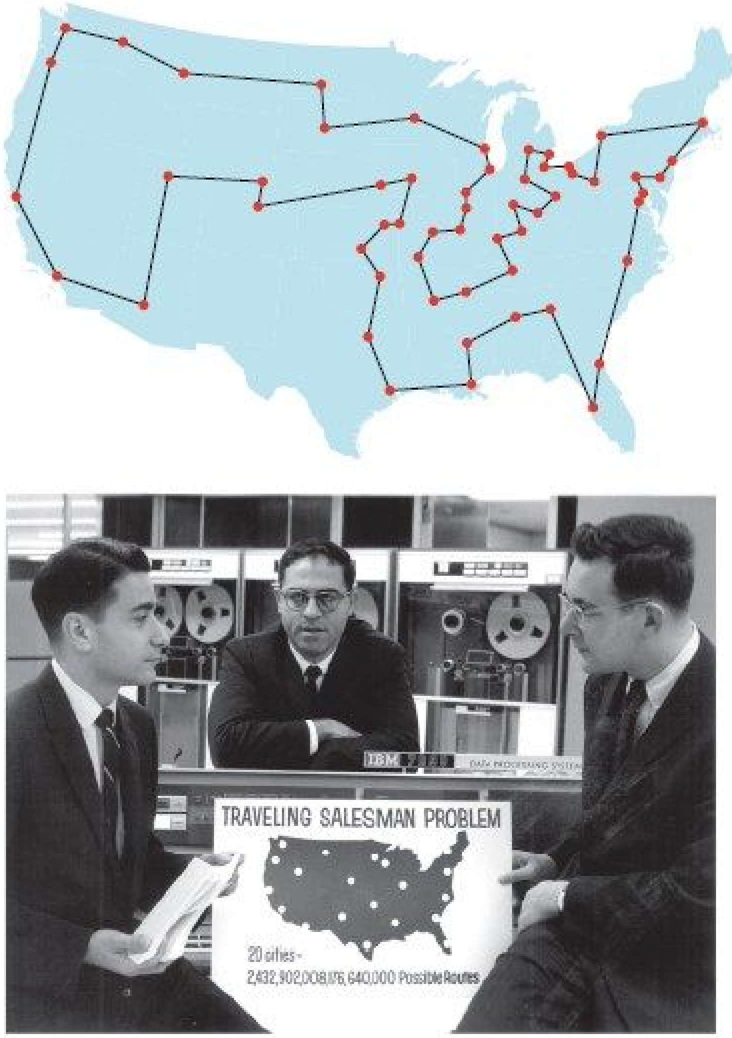
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2. Karp (1986).

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3. Interview with Richard Karp, October 24, 2009.



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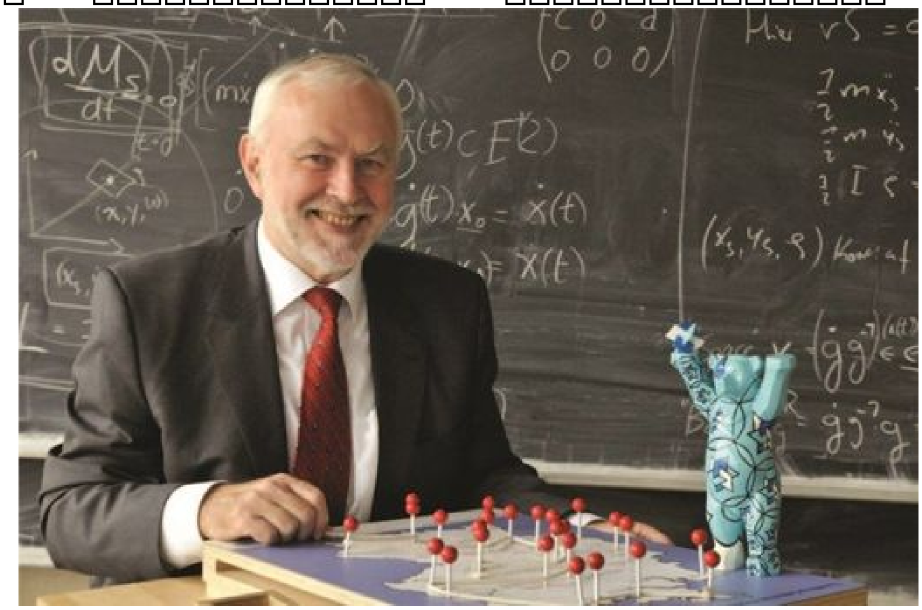
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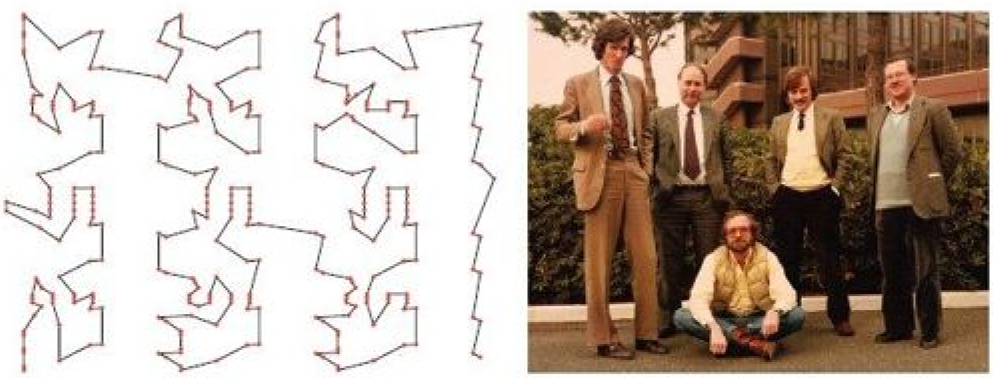
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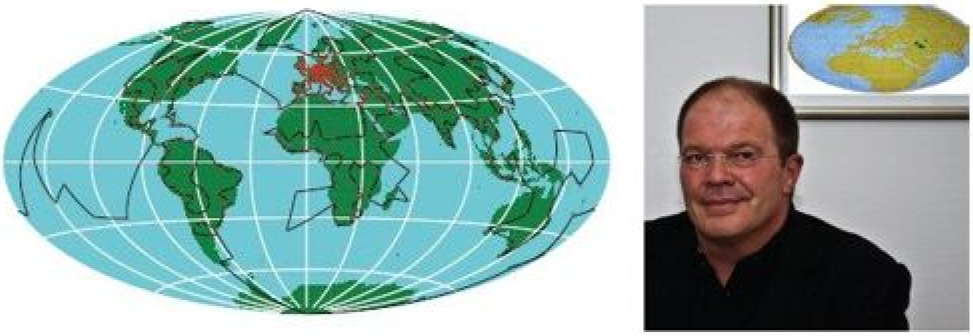
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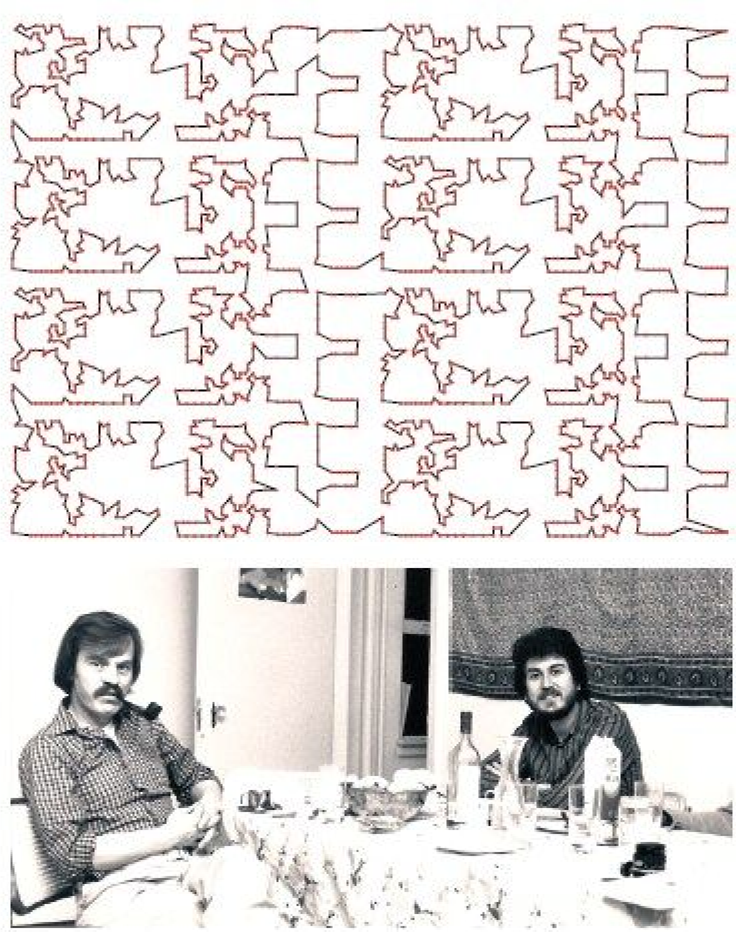
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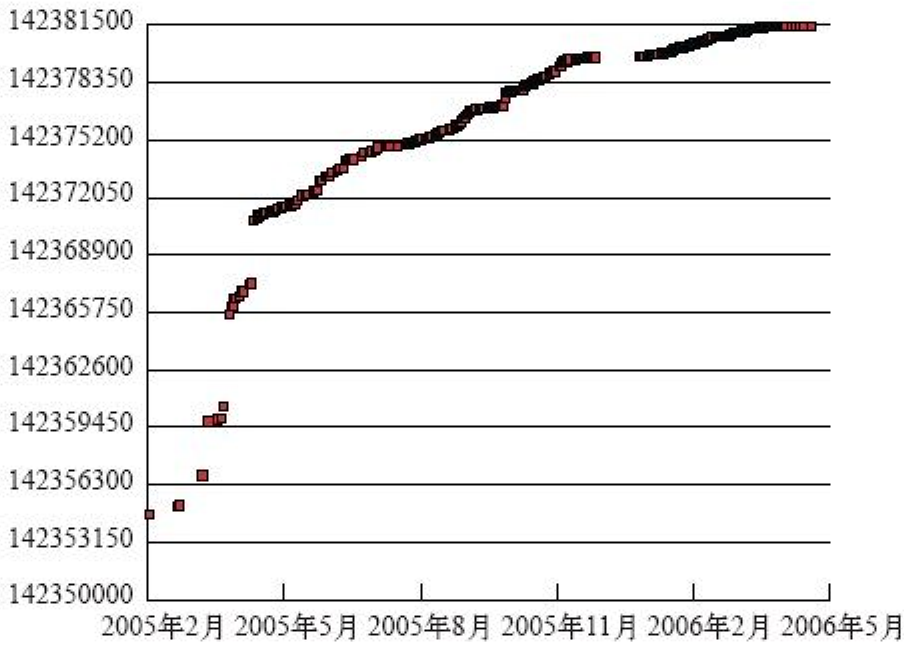
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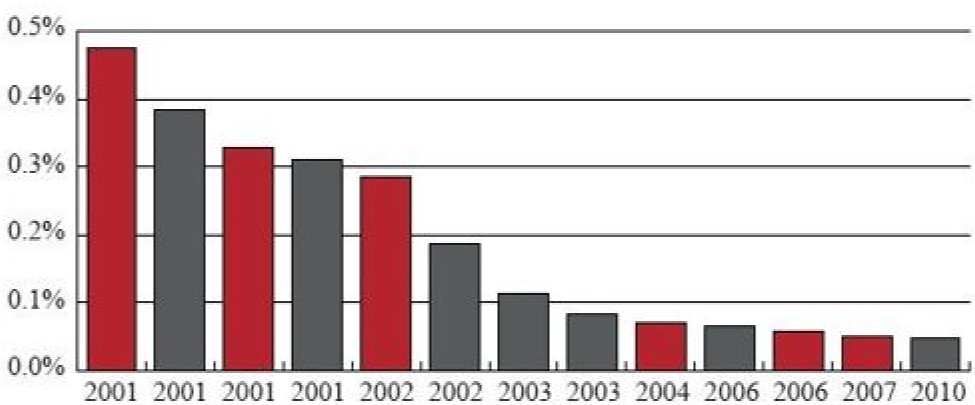
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[illegible]Concorde[illegible]

8.2.3 [illegible]

2003[illegible]Dave Applegate[illegible]TSP[illegible]USNO-A2.0[illegible]United States Naval Observatory A2.0 catalog[illegible]526 280 881[illegible]TSP[illegible]“[illegible]”[illegible]Enterprise[illegible][1][illegible]TSP[illegible]

1. “[illegible]”[illegible]——[illegible]

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> ——Jack Edmonds□1991□[1]

1. Edmonds (1991).

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9.1 [illegible]

[illegible]“[illegible]”[illegible]20[illegible]David Hilbert[illegible]Entscheidungsproblem[illegible]20[illegible]Kurt Gödel[illegible]·[illegible]Alonzo Church[illegible]·[illegible]Alan Turing[illegible]·[illegible]

[illegible]2300[illegible]Hilbert[illegible]1936[illegible]Turing machine[illegible][1]

1.Turing, A. M. 1936. Proc. Lond. Math. Soc. 42, 230–265.

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[illegible]

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	初始	奇数	偶数
0	_,向右,偶数	_,向右,奇数	_,向右,偶数
1	_,向右,奇数	_,向右,偶数	_,向右,奇数
_	0,_,停机	1,_,停机	0,_,停机

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2. [illegible]

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[illegible]iPhone[illegible]iPhone[illegible]

[illegible]iPhone[illegible]Universal Turing machine[illegible]

> [illegible]U[illegible]M[illegible]S.D.[illegible]U[illegible]M[illegible]

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9.2 Jack Edmonds[illegible]

David Hilbert[illegible]

[illegible]TSP[illegible]1953[illegible]Martin Beckmann[illegible]Tjalling Koopmans[illegible][1]

1. Beckmann, M., T. C. Koopmans. 1953. Cowles Commission: Econ. No. 2071.

> [illegible]

Beckmann[illegible]Koopmans[illegible]TSP[illegible]1954[illegible]Merrill Flood[illegible][2]

2. Flood (1954).

> [illegible]……[illegible]

Flood[illegible]TSP[illegible]“[illegible]”[illegible]20[illegible]50[illegible]

[illegible]Jack Edmonds[illegible]“[illegible]”[illegible]——[illegible]Edmonds[illegible]1954[illegible]“[illegible]”[illegible]Flood[illegible]Koopmans[illegible]Kuhn[illegible]



□9-2　1964□□□□□□□□□□□□□□Jack Edmonds□□□□ William Pulleyblank□□

Edmonds□□□□□□□□□□□□□□□□□□□□1961□□Dantzig□Fulkerson□Hoffman□□□□Edmonds□□□n^4□□□n□□□□□□□□□□□□□□□□□□□Edmonds□□□□□□□□□□□□□□□□□□□□□□□□□□□□□Edmonds□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□[3]

3. Edmonds (1991).

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□□□□□□□□□□nondeterministic Turing machine□□□Karp□□□□□□Cook□□□□□□□□□NP□

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1. Cook, S. 1971. In: *Proceedings of the 3rd Annual ACM Symposium on the Theory of Computing*. ACM Press, New York. 151–58.

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9.3.3 21[illegible]NP[illegible]

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[illegible]NP[illegible]NP[illegible]NP[illegible]Cook[illegible]NP[illegible]NP[illegible]NP[illegible]NP[illegible]

[illegible]Richard Karp[illegible][1][illegible]Cook[illegible]Karp[illegible]P[illegible]NP[illegible]21[illegible]NP[illegible]Cook[illegible]TSP[illegible]

1. Karp (1972).

Karp[illegible]NP[illegible]1979[illegible]Michael Garey[illegible]David Johnson[illegible]NP[illegible]*Computers and Intractability: A Guide to the Theory of NP-Completeness*[illegible]Garey-Johnson[illegible]NP[illegible][2]

2. Garey[illegible]Johnson[illegible]1979[illegible]Arora[illegible]Barack[illegible]2009[illegible]

9.3.4 [illegible]

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[illegible]P[illegible]NP[illegible]2009[illegible]Lance Fortnow[illegible]Wowbagger the Infinitely Prolonged[illegible]——[illegible]•[illegible]*The Hitchiker's Guide to the Galaxy*[illegible]

Wowbagger the Infinitely Prolonged[illegible]
TSP[illegible]“[illegible]”

9.4 TSP[illegible]

Gerhard Woeginger[illegible]“P[illegible]NP”[illegible]“[illegible]”[illegible]“[illegible]”[illegible][1][illegible]

1. [illegible]2013[illegible]44~46[illegible]47~49[illegible]——[illegible]

> 1. [Not equal]: In September 2008, J. J. proved . . .
> 2. [Not equal]: In October 2008, S. T. established . . .
> 3. [Equal]: In November 2008, Z. A. proved . . .

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> 1. [[illegible]][illegible]2008[illegible]9[illegible]J. J.[illegible]……
> 2. [[illegible]][illegible]2008[illegible]10[illegible]S. T.[illegible]……
> 3. [[illegible]][illegible]2008[illegible]11[illegible]Z. A.[illegible]……

Woeginger[illegible][2][illegible]25[illegible]“P=NP”[illegible]24[illegible]“P≠NP”[illegible]

2. [illegible]http://www.win.tue.nl/~gwoegi/P–versus-NP.htm[illegible]

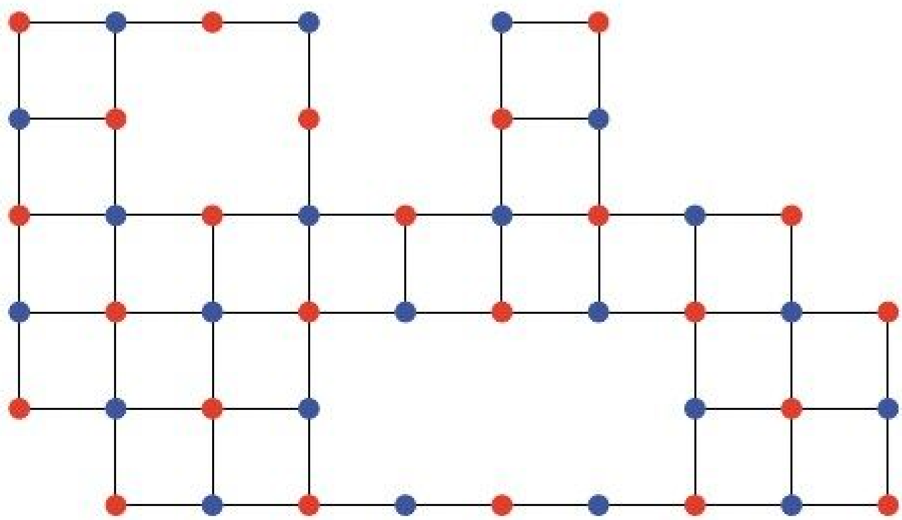
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9.4.1 [illegible]

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1. □Lawler (1985)□“Computational Complexity”□□□□□□□□□



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9.4.2 □□□□

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9.4.3 Held-Karp□□

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1. Held□Karp (1962).

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2. [illegible]Woeginger, G. J. 2003. Lect. Notes Comp. Sci. 2570, 185-207.

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9.4.6 Arora[illegible]

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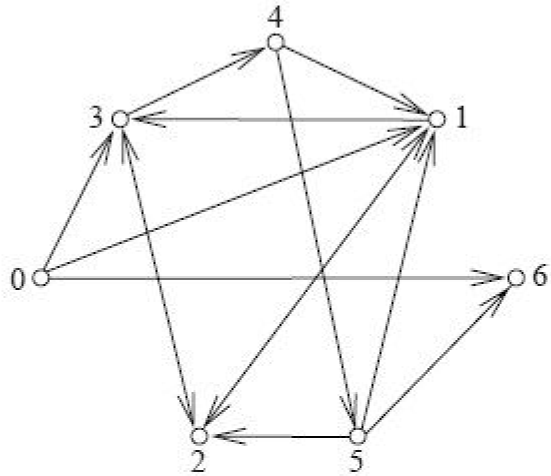
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9.5.1 DNA□□TSP

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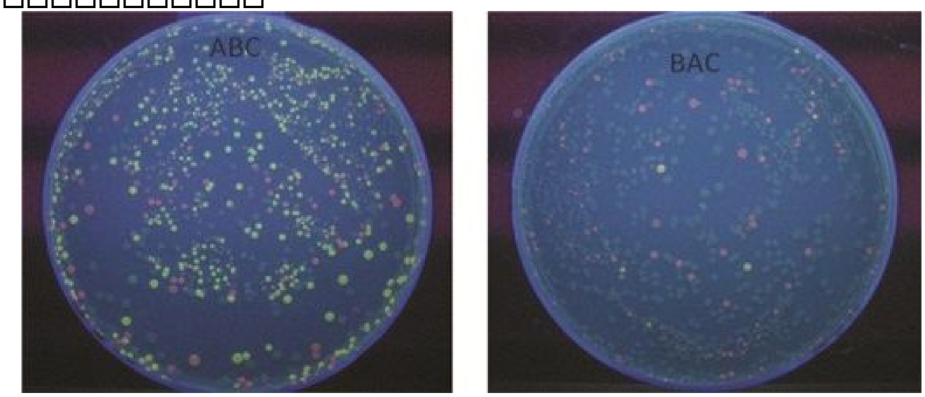
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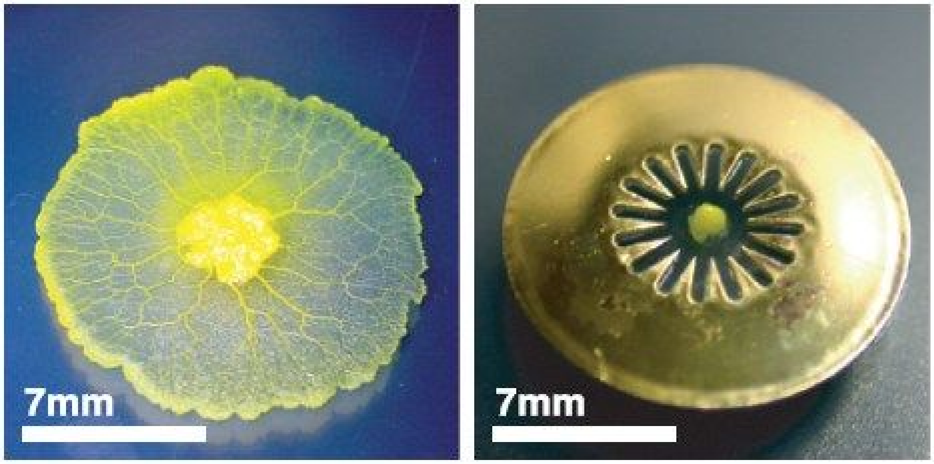
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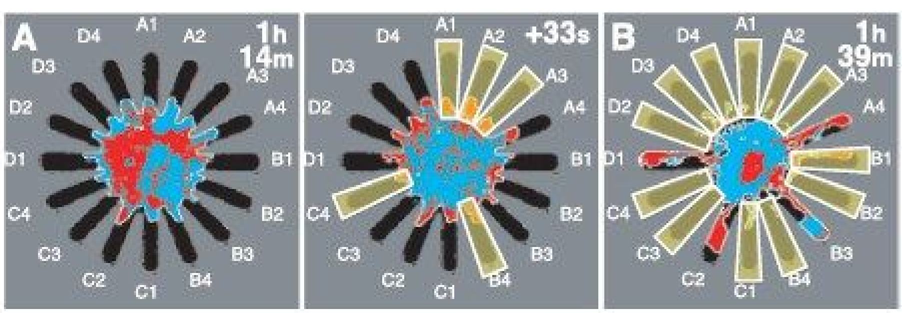
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9.5.5 [illegible]

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9.5.7 [illegible]

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> ——Charles Sheffield[illegible]1996[illegible][1]

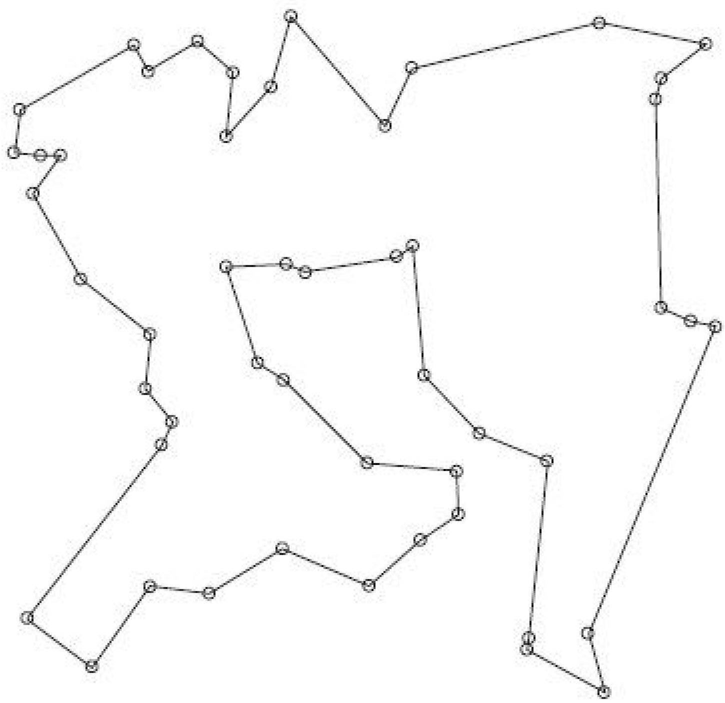
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1. [illegible]*Journal of Problem Solving*[illegible]TSP[illegible]Zygmunt Pizlo[illegible]



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10.2.1 [illegible]

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[illegible]Iris van Rooij[illegible][1][illegible]

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[illegible]7[illegible]12[illegible]TSP[illegible]5[illegible]10[illegible]15[illegible]5[illegible]10-1[illegible]

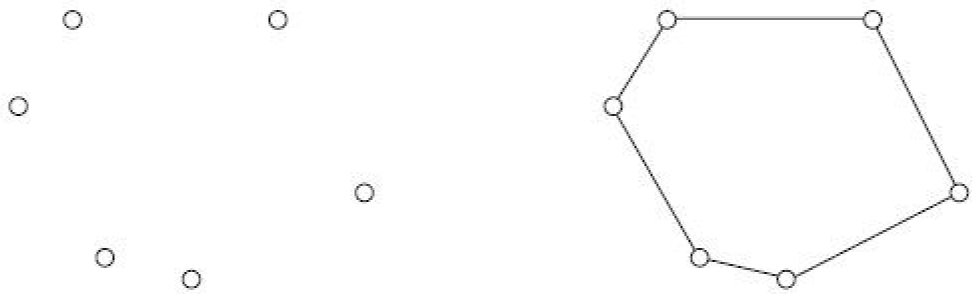
[illegible]10-1 [illegible]

[illegible]	**7[illegible]**	**12[illegible]**	[illegible]
5	3.8%	2.5%	1.7%
10	5.8%	3.4%	1.7%
15	9.4%	5.0%	2.7%

10.2.3 [illegible]

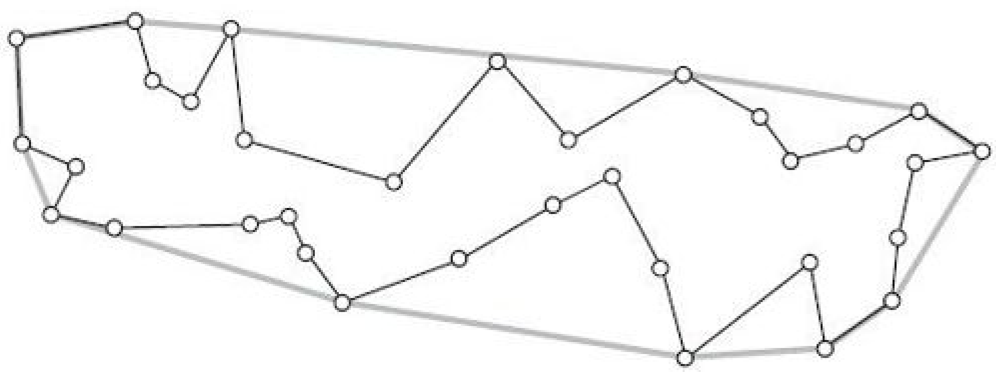
[illegible]James MacGregor[illegible]Thomas Ormerod[illegible][1][illegible]10-3[illegible]

1. MacGregor, J. N., T. Ormerod. 1996. Percept. Pyschophys. 58, 527–539.



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10.2.4 □□TSP□□

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1. Wiener, J. M., N. N. Ehbauer, H. A. Mallot. 2009. Psychol. Res. 77, 644–658.



□10-5 □□□□TSP□□□□Jan Wiener□□

10.3 □□□□□□TSP

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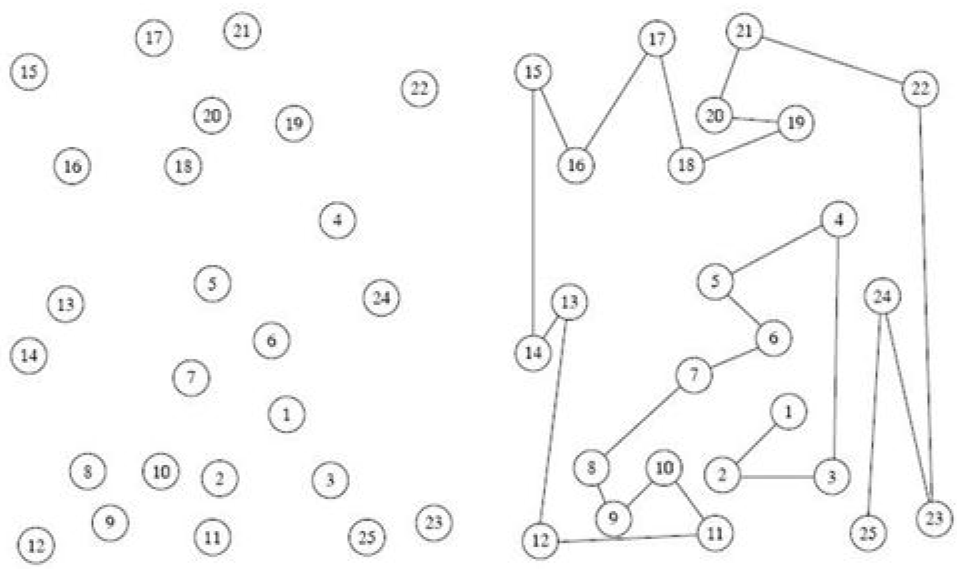
1. Vickers, D., et al. 2004. Pers. Indiv. Differ. 36, 1059–1071.

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1. Reitan, R. M., D. Wolfson. 1993. *The Halstead-Reitan Neuropsychological Test Battery: Theory and Clinical Interpretation*. Neuropsychology Press, Tucson, Arizona, USA.

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[illegible]1990[illegible][2][illegible]

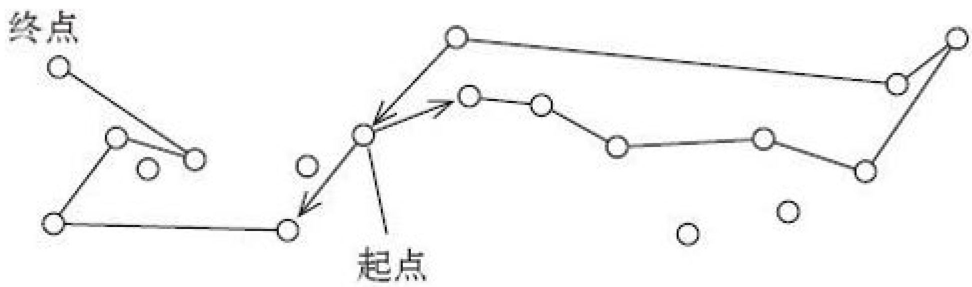
2. Butler, M., et al. 1991. Prof. Psychol.-Res. Pr. 22, 510–512.

10.4 [illegible]

[illegible]TSP[illegible]Emil Menzel[illegible]1973[illegible][1]Menzel[illegible]——[illegible]8[illegible]6[illegible]18[illegible]

1. Menzel, E. W. 1973. Science 182, 943–945.

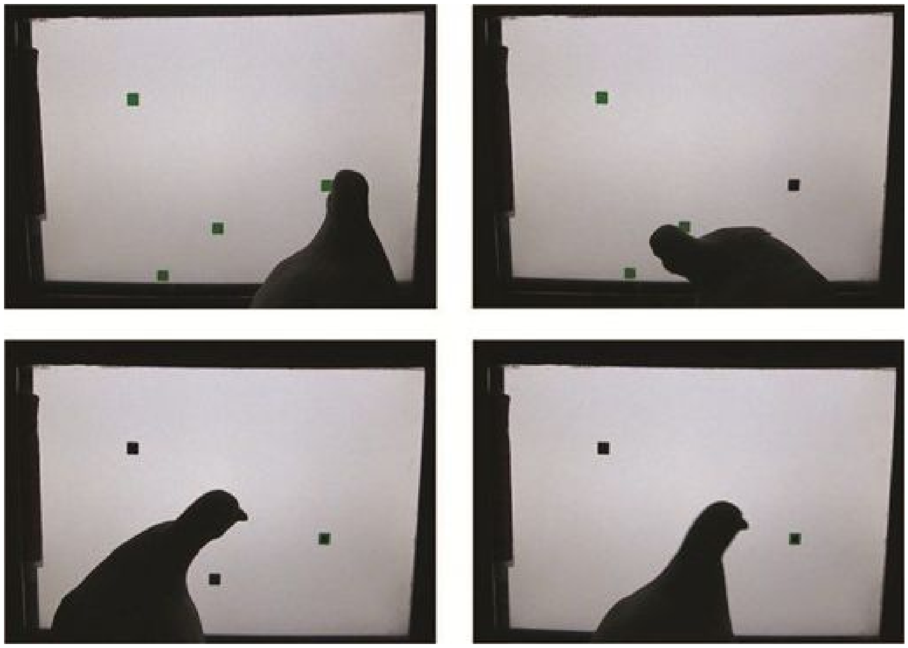
[illegible]Bido[illegible]10-7[illegible]Bido[illegible]“[illegible]”[illegible]“[illegible]”[illegible]4[illegible]



[illegible]10-7 [illegible]Bido[illegible]

[illegible]TSP[illegible]TSP[illegible]Brett Gibson[illegible][2][illegible]10-8[illegible]TSP[illegible]

2. Gibson, B. M., et al. 2007. J. Exp. Psychol. Anim. B. 33, 244–261.



□10-8 □□□□TSP□Brett Gibson□□

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>
> ——Jaroslav Nešetřil□1993□[1]

1. Nešetřil (1993).

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11.1 Julian Lethbridge

[illegible]Julian Lethbridge[illegible]Lethbridge[illegible]

> Julian Lethbridge[illegible]
>
> ——[illegible]1995[illegible][1]

1. *New York Times*, November 17, 1995, page C60.

> Lethbridge[illegible]
>
> ——ULAE[illegible]1997[illegible][2]

2. *Proof Positive: Forty Years of Contemporary American Printmaking at ULAE, 1957–1997*. Corcoran Gallery of Art, Washington, D.C., 1997.

> [illegible]
>
> ——Paula Cooper Gallery[illegible]1999[illegible][3]

3. Paula Cooper Gallery, Julian Lethbridge, March 26–April 24, 1999.

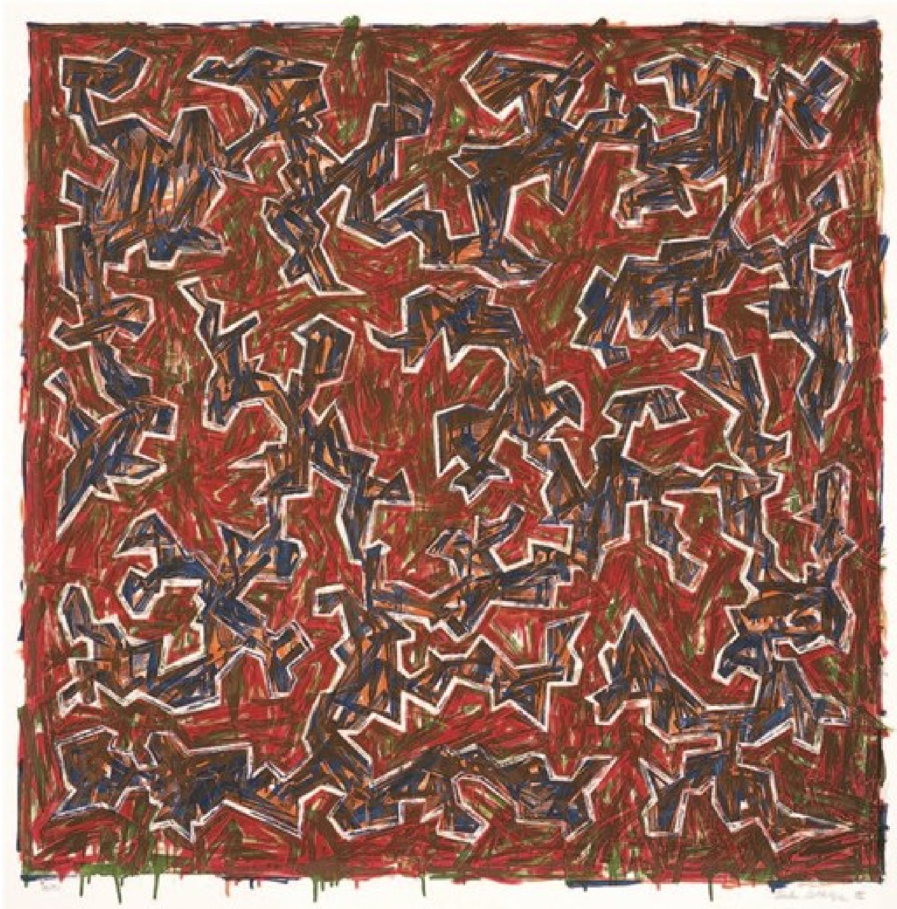
> [illegible]……[illegible]Lethbridge[illegible]
>
> ——Art in America[illegible]2007[illegible][4]

4. Harris, S. 2007. Art in America 95, issue 10, page 214.

[illegible]Lethbridge[illegible]

[illegible]TSP[illegible]11-1[illegible]11-2[illegible]*Baltimore Sun*[illegible]Jasper Johns[illegible]Jean Dubuffet[illegible]*Compagnie Fallacieuse*[illegible][5]TSP[illegible]Lethbridge[illegible]

5. *New York Times*, November 17, 1995, page C60; *Baltimore Sun*, March 31, 1996.



□11-1 □□□□□Julian Lethbridge□1995□□□□□1.11□×1.07□□43.75□□×42□□□□Julian Lethbridge□United Limited Art Editions□□□



□11-2　□□□□□□□□□□Julian Lethbridge□1995□□□□□□□ □□□1.83□×1.83□□72□□×72□□□□Robert and Jane Meyerhoff Collection□□□Adam Reich□□□

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□11-2□□□□□□□□□□□□□□□□□□□□□□□Lethbridge□□Meyerhoff Collection□

11.2 [illegible]

[illegible]11-3[illegible]Robert Bosch[illegible]*Embrace*[illegible]2010[illegible]Mathematical Art Exhibition[illegible]



[illegible]11-3 [illegible]TSP[illegible]Robert Bosch[illegible]

Robert Bosch[illegible]1[illegible]100 000[illegible]TSP[illegible]Bosch[illegible][1]

1. Bosch, R. 2010. Embrace. *2010 Joint Mathematics Meetings Art Exhibition Catalog*.

> [illegible]——[illegible]

Bosch[illegible]TSP[illegible]TSP[illegible]1[illegible]Craig Kaplan[illegible]TSP[illegible][2]

2. Kaplan, C., R. Bosch. 2005. Proceedings of the Bridges 2005 Conference.

[illegible]Bosch-Kaplan[illegible]TSP[illegible]Bosch[illegible]“[illegible]”[illegible]bending

the curve to our will[illegible][3][illegible]TSP[illegible]“[illegible]TSP[illegible]”[illegible]TSP[illegible]Bosch[illegible]

3. Bosch. R. 2009. Proceedings of the Bridges 2009 Conference.

[illegible]0.6[illegible][4][illegible]726[illegible]TSP[illegible]

4. [illegible]——[illegible]

Bosch[illegible]11-3[illegible]

> [illegible]TSP[illegible]

[illegible]TSP[illegible]2840[illegible]

Philip Galanter[illegible]TSP[illegible]

Bosch[illegible]Lethbridge[illegible]TSP[illegible]Bosch[illegible]Lethbridge[illegible]Philip Galanter[illegible]TSP[illegible]11-4[illegible]TSP[illegible]



[illegible]11-4 TSP[illegible]Philip Galanter[illegible]

Galanter[illegible]TSP[illegible][1]

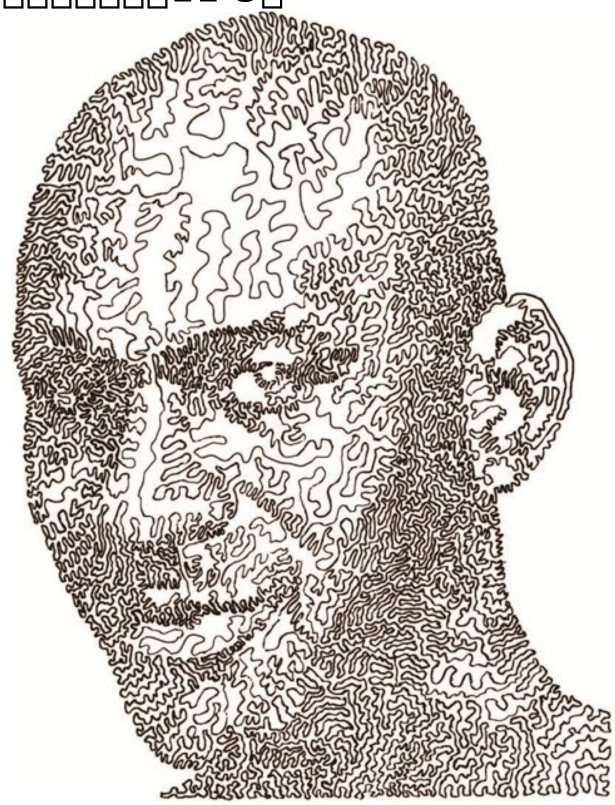
1. Galanter, P. 2009. Artist text. Artware 5 Exhibition, Lima, Peru, May 2009.

> [illegible]

Galanter[illegible]TSP[illegible]16[illegible]4.9[illegible]

11.3 □□□□□□□

□□J. Eric Morales□□□□□□□□□□□□□Mo□□□□□□□□□□□□□□□□□□□□□□□□□“□□□□”□Labyrinthine Projection□□Mo□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□□iPod□□□□□□□□□□□□□□·□□□□□□11-5□



□11-5 □□□□□□□·□□J. Eric Morales (www.labyrinthineprojection.com)□□□

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[illegible][1]

1. [illegible]A. Secord[illegible]Voronoi diagram[illegible]

11.4 [illegible]

[illegible]Jaroslav Nešetřil[illegible]Jaroslav Nešetřil[illegible]Jiří Načeradský[illegible]11-7[illegible]



[illegible]11-7 Jiří Načeradský[illegible]Jaroslav Nešetřil[illegible]1997[illegible]100cm×120cm[illegible]Jaroslav Nešetřil[illegible]

[illegible]Nešetřil[illegible]-[illegible]“[illegible]”[illegible]Creative Thesis[illegible]“[illegible]”[1]Nešetřil[illegible]

1. Nešetřil(1993).

[illegible]

[illegible]Nešetřil[illegible]Bernhard Korte[illegible]Arithmeum[illegible]11-8[illegible]

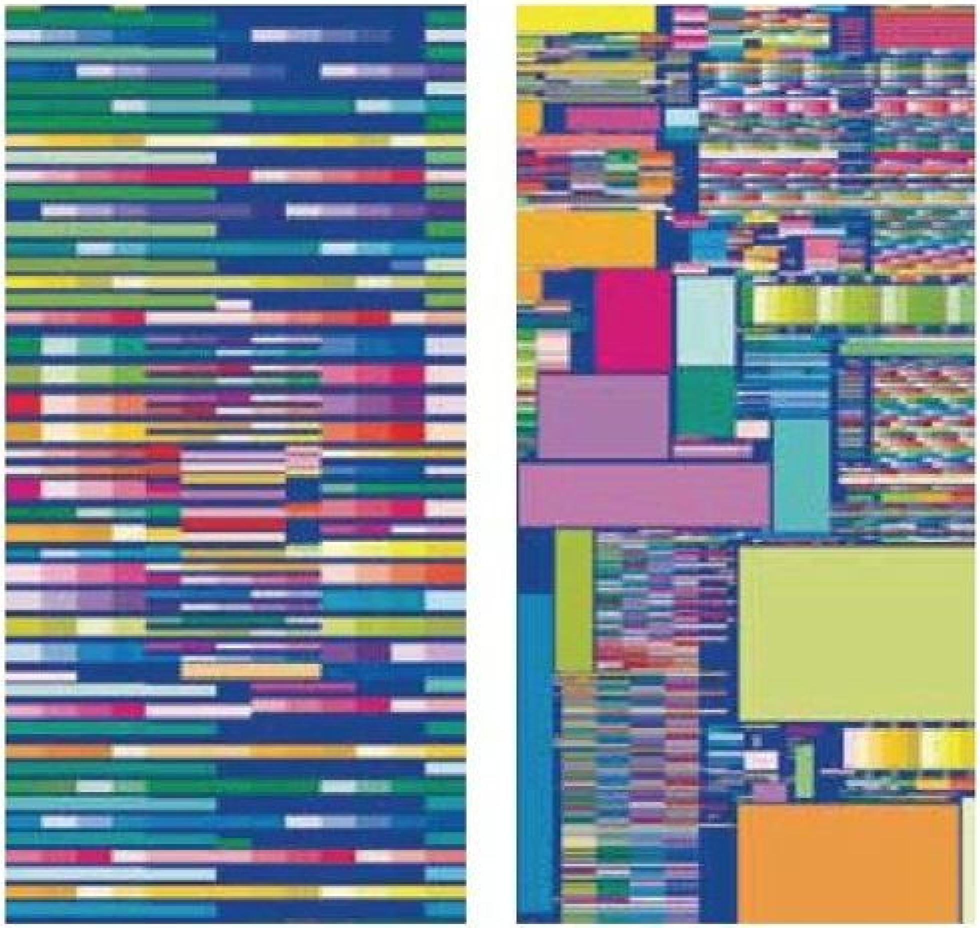


[illegible]11-8 [illegible]Bernhard Korte[illegible]

[illegible]Bernhard Korte[illegible]“[illegible]”[1][illegible]Josef Albers[illegible]Max Bill[illegible]Jean Gorin[illegible]Richard Paul Lohse[illegible]Leon Polk Smith[illegible]Charmion von Wiegand[illegible]

1. Korte, B. 1991. *Mathematics, Reality, and Aesthetics – A Picture Set on VLSI-Chip-Design*. Springer Verlag, Berlin.

[illegible]VLSI[illegible]VLSI[illegible]10[illegible]VLSI[illegible]11-9[illegible]Ina Prinz[illegible]



[illegible]11-9 “Philipp”[illegible]Ina Prinz[illegible]
Nešetřil[illegible]VLSI[illegible]“[illegible]”[illegible][2]

2. Nešetřil (1993).

> [illegible]

[illegible]TSP[illegible]TSP[illegible]

[illegible]12[illegible] [illegible]

> [illegible]
>
> ——Delbert Ray Fulkerson[illegible]1956[illegible][1]

1. [illegible]D. R. Fulkerson[illegible]1956[illegible]6[illegible]25[illegible]Neuilly[illegible]B. Zimmern[illegible]

[illegible]TSP[illegible]

> Christos Papadimitriou[illegible]
>
> ——Jon Bentley[illegible]1991[illegible][2]

2. *New York Times*, 1991-03-12, G. Kolata.

> [illegible]
>
> ——Vašek Chvátal[illegible]1998[illegible][3]

3 Science Blog, 1998-06-08. http://www.scienceblog.com.

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[illegible]4/3[illegible]Held-Karp[illegible]Christofide[illegible]TSP[illegible]

[illegible]Avi Widgerson[illegible]P=NP[illegible]P≠NP[illegible]

[illegible]TSP[illegible]P≠NP[illegible]

[illegible]TSP[illegible]Rashers Ronald[illegible]

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